DEPARTMENT OF DEFENSE

Technology Readiness Assessment (TRA) Deskbook

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EXECUTIVE SUMMARY

The body of this document is a concise description of procedures for meeting the Technology Readiness Assessment (TRA) requirements of the Defense Acquisition System (DAS). The intent is to provide the Director of Defense Research and Engineering (DDR&E) staff participants a working appreciation of the overall TRA process, with enough detail to allow them to meet their staff responsibilities. The potential benefit to other Office of the Secretary of Defense (OSD) and Service Component participants is also recognized. This deskbook should give those involved with TRAs a greater understanding of how TRAs fit into Defense acquisition and what is expected by the DDR&E.

The recently revised Department of Defense (DoD) acquisition system is documented in the following documents, each of which is available at http://dod5000.dau.mil/:

- ***The Defense Acquisition System*, dated October 30, 2002.** This document is herein referred to as *Attachment 1* and replaces DoD Directive (DoDD) 5000.1.
- ***Operation of the Defense Acquisition System*, dated October 30, 2002.** This document is herein referred to as *Attachment 2* and replaces DoD Instruction (DoDI) 5000.2.
- ***Interim Defense Acquisition Guidebook*, dated October 30, 2002.** This document is herein referred to as *Interim Guidebook*. It provides non-mandatory guidance drawn from the earlier DoD Regulation 5000.2-R.

The first two of these documents are attachments to a memorandum signed by the Deputy Secretary of Defense.[1]

A central theme of the acquisition process is that the technology employed in system development should be "mature" before system development begins. Normally, for technology to be considered mature, it must have been applied in a prototype article (a system, subsystem, or component), tested in a relevant or operational environment, and found to have performed adequately for the intended application. This implies a need for a way to measure maturity and for a process to ensure that only sufficiently mature technology is

1 Deputy Secretary of Defense Memorandum, Subject: *Defense Acquisition*, dated October 30, 2002. This memorandum is available at http://dod5000.dau.mil/.

employed. *Attachment 1* states basic policy for Defense acquisition. *Attachment 2* establishes a flexible management framework for acquisition programs and, among other things, a requirement for TRAs.

The *Interim Guidebook* provides an outline of a process and suggests activities for performing TRAs; however, this guidance is not mandatory. The document introduces Technology Readiness Levels (TRLs) as an accepted way to describe technology maturity and suggests activities that could be carried out by Program Managers (PMs), Component Science and Technology (S&T) Executives, Component Acquisition Executives (CAEs), and the DDR&E. [**Note:** *The current edition of the Interim Guidebook assigns certain responsibilities to the Deputy Under Secretary of Defense for Science and Technology (DUSD(S&T)). A later agreement assigns these responsibilities to the DDR&E. The Office of the Director of Defense Research and Engineering (ODDR&E) staff proponent for TRAs is the DUSD(S&T)*].

A set of appendixes provides summaries of the TRA process and its implementation (Appendix A), extracts from current guidance that is relevant to the TRA process (Appendix B), SEC. 804 of the NDAA for Fiscal Year 2002, Conference Report (Appendix C), and TRL examples (Appendix D). The expectation is that the basic architecture of the TRA process will remain relatively stable over time, whereas the details implementing the process will evolve, grow, or perhaps even become simpler over time. As changes occur, adapting the appendixes or adding new appendixes will provide an effective way for the deskbook to accommodate these changes.

I. INTRODUCTION

1.1 BACKGROUND

Recent interim guidance for the Department of Defense (DoD) acquisition system is documented in two attachments to a memorandum from the Deputy Secretary of Defense.[2] Herein, these attachments will be referred to as *Attachment 1* and *Attachment 2*. Additional, nonmandatory guidance on best practices, lessons learned, and expectations is available in an *Interim Guidebook*.[3] It is anticipated that these policy and guidance documents will be revised in the near future.

A central theme of the acquisition process is that the technology employed in system development should be "mature" before system development begins.[4] Normally, for technology to be considered mature, it must have been applied in a prototype article (a system, subsystem, or component), tested in a relevant or operational environment, and found to have performed adequately for the intended application. This implies a need for a way to measure maturity and for a process to ensure that only sufficiently mature technology is employed.

Attachment 2 establishes a requirement for Technology Readiness Assessments (TRAs), and the *Interim Guidebook* provides an outline of a process for performing TRAs. These documents introduce Technology Readiness Levels (TRLs) as an accepted way to describe technology maturity. The National Aeronautics and Space Administration (NASA) has defined TRLs and has used them in its program reviews, and the NASA definitions are the basis for the DoD definitions. A readiness level of TRL 6 or, preferably, TRL 7 is

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2 Deputy Secretary of Defense Memorandum, Subject: *Defense Acquisition*, dated October 30, 2002. The two attachments to this memorandum are *The Defense Acquisition System,* dated October 30, 2002 *(Attachment 1)* and the *Operation of the Defense Acquisition System,* dated October 30, 2002 *(Attachment 2)*. These attachments are herein referred to as *Attachment 1* and *Attachment 2*. This memorandum and the two attachments are available at http://dod5000.dau.mil/.

3 The *Interim Defense Acquisition Guidebook*, dated October 30, 2002, is also available at http://dod5000.dau.mil/. This document in herein referred to as the *Interim Guidebook*.

4 This reflects a major conclusion of a study performed by the General Accounting Office (GAO). See Appendix A.

normally achieved before a technology is used in system development. Section III of this document addresses TRLs in some detail.

To carry out TRAs, the guidebook describes actions that would normally be taken by Program Managers (PMs), Component Science and Technology (S&T) Executives, Component Acquisition Executives (CAEs), and the Director of Defense Research and Engineering (DDR&E).[5] TRAs must be carried out before Milestone B and Milestone C of acquisition programs categorized as Acquisition Category One (ACAT I): ACAT ID[6] or ACAT IAM.[7]

1.2 PURPOSE OF THIS DOCUMENT

This document is intended to provide DDR&E staff participants a working appreciation of the overall TRA process, with enough detail to allow them to meet their staff responsibilities. The potential benefit to other Office of the Secretary of Defense (OSD) and Service Component participants is also recognized. This "deskbook" should give those involved with TRAs a greater understanding of how TRAs fit into Defense acquisition and what is expected by the DDR&E.

1.3 ORGANIZATION OF THIS DOCUMENT

The body of this document is a concise description of the responsibilities and procedures for meeting the TRA requirements of the Defense Acquisition System (DAS). A set of appendixes provides the following: summaries of the TRA process and its

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5 The current edition of the *Interim Guidebook* (dated October 30, 2002) assigns this responsibility to the Deputy Under Secretary of Defense for Science and Technology (DUSD(S&T)). A later agreement assigns this responsibility to the DDR&E. The Office of the Director of Defense Research and Engineering (ODDR&E) staff proponent for TRAs is the DUSD(S&T).

6 An ACAT ID is a subcategory of the ACAT I program. ACAT I programs are Major Defense Acquisition Programs (MDAPs) or programs that the Milestone Decision Authority (MDA) designates ACAT I. An MDAP is an acquisition program that is not a highly sensitive classified program (as determined by the Secretary of Defense) and is designated by the Under Secretary of Defense for Acquisition, Technology, and Logistics USD(AT&L) as an MDAP or is estimated to cost more than certain specified amounts. The MDA for ACAT ID programs is the USD(AT&L). The "D" in ACAT ID refers to the Defense Acquisition Board (DAB), which advises the USD(AT&L) at major decision points.

7 An ACAT IAM is a subcategory of the ACAT IA program. ACAT IA programs are Major Automated Information Systems (MAISs) or programs designated by the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)) to be ACAT IA. The MDA for the ACAT IAM programs is the DoD Chief Information Officer (CIO), who is the ASD(C3I). The "M" in ACAT IAM refers to MAISs.

implementation, extracts from current guidance that is relevant to the TRA process, formal items relevant to the TRA process, and TRL examples. The expectation is that the basic architecture of the TRA process will remain relatively stable over time, whereas the details implementing the process will evolve, grow, or perhaps even become simpler over time. As changes occur, adapting the appendixes or adding new appendixes will provide an effective way for the deskbook to accommodate these changes.

1.4 ACQUISITION PROCESS OVERVIEW

Figure I-1 shows the architecture, or framework, of the Defense acquisition process. An acquisition program is normally established in response to a recognized user need, but it can also be established to exploit a technological opportunity that might result in a new military capability, a reduced cost, or other benefit. Within this framework, each program can be structured to achieve the best balance of cost, schedule, and performance.

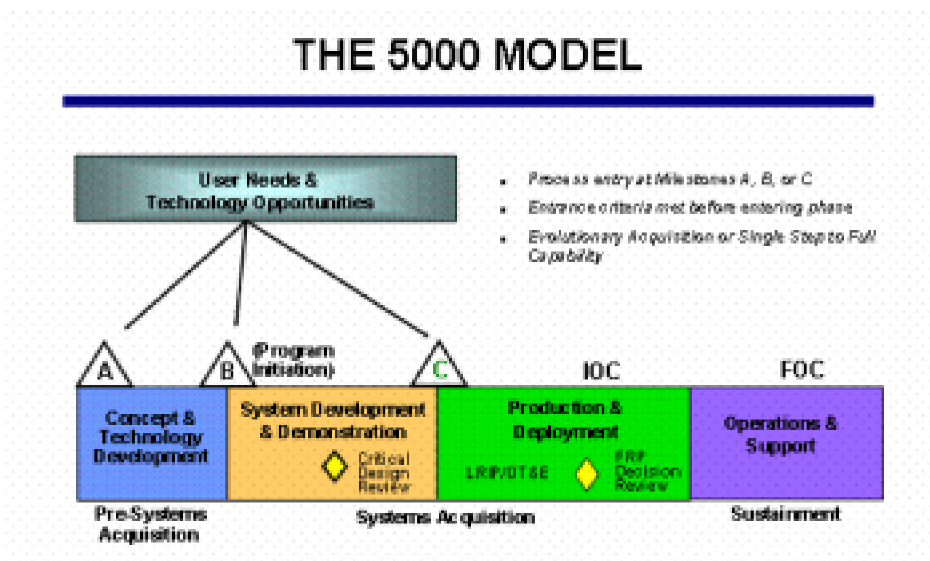

Figure I-1. Defense Acquisition Management Framework (Source: *Attachment 2*)

After a military need or a technological opportunity has been recognized, the Joint Staff and multiple DoD communities examine multiple concepts and materiel approaches to assist in formulating operational goals and requisite capabilities. A preferred concept is then described in an Initial Capabilities Document (ICD), which serves as a starting point for concept refinement. The Milestone Decision Authority (MDA) designates the lead DoD Component(s) to analyze alternatives and refine the initial concept. Concept refinement typically consists of competitive, parallel, short-term concept studies guided by the ICD. These studies focus on refining and evaluating the feasibility of alternative solutions to the initial concept and providing a basis for assessing the relative merits of these solutions. Concept refinement should identify technologies that provide advantages and that should be developed further to support the preferred concept.

Technology Development is a continuous technology discovery and development process that reflects a close collaboration between the user and the system developer. This phase reduces technology risk and determines which technologies should be integrated into a system. Technology Development demonstrations can be used to substantiate technology maturity. One of the criteria for exiting Technology Development is that the technology[8] has been demonstrated in a relevant environment. This phase produces a Capability Development Document (CDD) that builds on the ICD and supports the initiation of an acquisition program. The CDD provides the detailed operational performance parameters necessary to design the proposed system.

A TRA is required before Milestone B and before Milestone C.

A Milestone B review initiates System Development and Demonstration (SDD), which marks the entry into an acquisition program. *Attachment 2*, paragraph 3.6.2.2 requires that "Technology … shall have been demonstrated in a relevant environment or, preferably, in an operational environment to be considered mature enough to use for product development in systems integration. Technology readiness assessments, and where necessary, independent assessments, shall be conducted. If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet user's needs."

SDD consists of two major efforts (System Integration and System Demonstration), with a mid-phase Critical Design Review (CDR). During System Integration, subsystems and components are integrated into systems and the resulting prototypes are demonstrated. During System Demonstration, the system is demonstrated in its intended environment using engineering development models (EDMs) or commercial items.

Attachment 2, paragraph 3.7.1 states that "Milestone C authorizes entry into Low-Rate Initial Production (LRIP) (for MDAPs and major systems), into production or procurement (for non-major systems that do not require LRIP) or into limited deployment for MAIS programs or software-intensive systems with no production components." During

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8 This technology refers to that needed for the program or, for evolutionary development, for an increment of the program.

LRIP, a sufficient number of systems are produced to support Initial Operational Test and Evaluation (IOT&E) and Live Fire Test and Evaluation (LFT&E), if required, and to provide the Initial Operational Capability (IOC). LRIP provides an opportunity to assess the adequacy of the manufacturing technology, processes, and plant being used for the program.

The framework just described can be tailored to the specific acquisition program structure. For example, the program does not have to start at Milestone A. It can start at Milestone B or some other place between Milestone A and Milestone C. If it starts at or beyond Milestone B, an associated TRA will be conducted to ensure that the technology is ready for the upcoming phase of acquisition.

Attachment 2 (paragraphs 3.3.2., 3.3.2.1., and 3.3.2.2.) establishes evolutionary development as the strategy preferred by DoD:

> The approaches to achieve evolutionary acquisition require collaboration between the user, tester, and developer. They include the following:
>
> > Spiral Development. In this process, a desired capability is identified, but the end-state requirements are not known at program initiation. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation.
> >
> > Incremental Development. In this process, a desired capability is identified, an end-state requirement is known, and that requirement is met over time by development of several increments, each dependent on available mature technology."

Hardware systems are normally developed using the incremental development process. Each successive design unit is called an increment (Increment 1, Increment 2, and so forth). To ensure that the technology is mature, a TRA is required for each increment before the program has a Milestone B or Milestone C review for that increment.[9]

Software is normally developed using the spiral development process. This is an iterative, cyclical process of build-test-fix-test-deploy. Each release builds on the lessons of the previous release. There can be several releases during the acquisition and deployment of a system or system increment. In the TRA process, software is considered an integral part of the system or subsystem in which it operates.

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9 Paragraphs 3.6.1 and 3.6.2.2 and C.T2. Table 2. of *Attachment 2*.

II. KEY ACTIVITIES AND RELATIONSHIPS

Much of the material in the following paragraphs is based on the *Interim Guidebook*; however, the responsibilities and processes in the guidebook (which is based on DoD 5000.2-R) are not mandatory. Therefore, the following is a "suggestion" of activities and relationships that can accomplish the required TRAs.

Before an acquisition program can enter SDD (at Milestone B) or LRIP (at Milestone C), technology maturity must be assessed.[10] *Attachment 2*, paragraph 3.6.2, establishes as acquisition policy that "… Unless some other factor is overriding in its impact, the maturity of the technology shall determine the path to be followed." Paragraph 3.6.2.2 states that "… If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs."

The PM is an especially important figure in Defense acquisition. He/she is responsible for planning and managing each program. The PM normally[11] reports to a Program Executive Officer (PEO), who oversees several PMs. The PEO reports directly to the CAE, who reports through the Component Secretary to the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)). Similarly important is the Component S&T Executive. He/she reports to the CAE and is responsible for developing the noncommercial technologies that the Component will need to meet future operational requirements. DDR&E has an oversight responsibility for this Technology Development program as part of managing the overall S&T program within DoD.

The *Interim Guidebook* suggests that the Component S&T Executive should be responsible for directing the Component TRAs. For ACAT I and ACAT IA programs, these TRAs are submitted to the CAE for approval, and an information copy is sent to the DDR&E. Subsequently, the CAE transmits the action version of the TRA to the DDR&E, who is responsible for evaluating each TRA received from a Component.

During concept refinement, the technologies required to develop the system are identified. Whenever the system concept requires technologies that are still being developed

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[10] This is a regulatory requirement. See Tab C of *Attachment 2*.

[11] For a few special programs, the PM reports directly to the CAE.

by Component S&T organizations or industry, the Component can develop a Technology Development strategy to be pursued during Technology Development so that the technology needed in SDD will be sufficiently mature by Milestone B.

Determining a technology's maturity involves the participation of the PM, the Component S&T Executive, and the DDR&E.[12] Figure II-1 is a nominal timeline for the required TRA activities. Figure II-2 displays the principal activities of the DDR&E Action Officer (AO).

The following paragraphs describe the key activities and people involved in the TRA process. Section IV of this document explores the TRA process in detail.

2.1 PROGRAM MANAGER (PM)

2.1.1 Requesting Milestone Review Meetings

Most likely, a PM will be designated during Technology Development to guide that development and to prepare for Milestone B. The PM is responsible for requesting the milestone review meetings. For ACAT ID programs, the Defense Acquisition Board (DAB)[13] conducts the review. For ACAT IAM programs, a group assembled by DoD's Chief Information Officer (CIO)[14] conducts the review.

Concurrently with scheduling a milestone review meeting, the PM establishes a schedule for the submission of critical technologies. When establishing the schedule for submitting critical technologies, coordinating with the Component S&T Executive (and with the DDR&E for ACAT ID and ACAT IAM programs) is important so that each organization has ample time to complete its respective TRA activities.

2.1.2 Determining Critical Technologies and Disseminating Information

The PM has a fundamental responsibility to know which technologies are critical. A technology is "critical" if the system being acquired depends on this technology to meet the

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12 Appendix B includes from *Attachment 1*, *Attachment 2*, and the *Interim Guidebook* extracts that assign TRA responsibilities.

13 The DAB is chaired by the USD(AT&L), who is the MDA for ACAT ID programs. The Vice Chairman of the Joint Chiefs of Staff (VCJCS) serves as the vice chairman.

14 The meeting is chaired by the ASD(C3I), who is the DoD CIO and MDA for ACAT IAM programs.

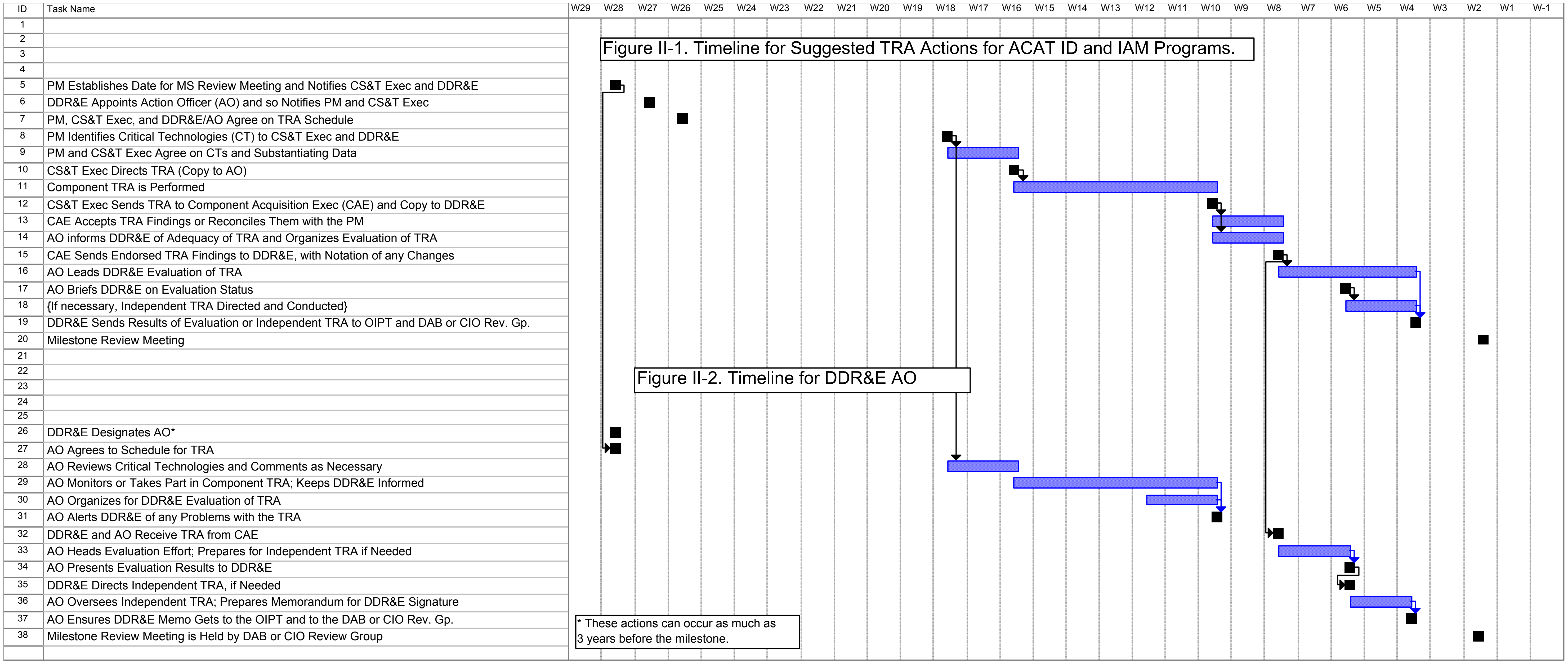

Figure II-1. Timeline for Suggested TRA Actions for ACAT ID and IAM Programs
and
Figure II-2. Timeline for DDR&E AO

system operational requirements (including key performance parameters and cost) in development, production, and operation *and* if the technology or its application is either new or novel. Said another way, a new or novel technology is critical if it is necessary to achieve the successful development of a system, its acquisition, and its operational utility.

About 16 weeks before a milestone review (see Figure II-1), on the schedule agreed to with the DDR&E and the Component S&T Executive, the PM should identify the critical technologies and compile the status, test results, and other information necessary to assess the maturity of these technologies. This identification of critical technologies is a critical step in the TRA process. For a readiness assessment to be useful, it must include all the critical technologies. However, before identifying the critical technologies, it would be helpful if the PM would send the DDR&E and the Component S&T Executive a memorandum that describes the process that will be used.

After determining the critical technologies, the PM provides this information to the Component S&T Executive and sends an information copy to the DDR&E. Preferably, the identification of critical technologies will have been vetted and agreed upon between the PM and Component S&T Executive. In addition to the list of critical technologies, the PM should explain the function of each technology in the system and provide information on the status of each technology. This could include records of tests or applications of the technology. The PM should also provide additional information as requested by the Component S&T Executive or the DDR&E.

If an ACAT ID or ACAT IAM program integrates critical systems that are being developed in other programs, the PM of the higher order program (the "system-of-systems" program) is responsible for the technologies—including interface technologies—used on his/her side of the interfaces for the TRA. This PM should request (through the appropriate PEO or CAE, as necessary) and obtain the identification of any critical technologies on which the lower order programs depend.

If a program has competing designs at the time of the Milestone B or Milestone C review, the critical technologies of each design should be identified separately.

2.2 COMPONENT SCIENCE AND TECHNOLOGY (S&T) EXECUTIVE

2.2.1 Providing the Required Technology

The Component S&T Executive is responsible for developing the noncommercial technologies that will be needed to meet future operational requirements. In addition to advising PMs regarding the status and applicability of technologies, the Component S&T Executive should work with the PMs to establish how technologies will be matured to support system development programs. During Technology Development, prior to MS B, the Component S&T Executive and Component laboratories will likely be providing some of the resources and effort that the PM has identified in the Technology Development strategy.

2.2.2 Directing the TRA

The *Interim Guidebook* suggests that the Component S&T Executive should direct the TRA and decide how it will be conducted. The TRA must include all critical technologies identified by the PM and can include additional technologies that the Component S&T Executive considers critical. Typically, much of the information used in a TRA comes from the PM; however, the assessment *must be independent* of the PM.

The TRL definitions (see Section III, Table III-1) provide a convenient and unambiguous nomenclature for a technology's maturity status. The Component should use TRLs to relate TRA findings unless alternative means have been coordinated beforehand with the DDR&E.

2.2.3 Processing the TRA Results

For ACAT ID and ACAT IAM programs, the Component S&T Executive signs the TRA (or accompanying memorandum) and accepts responsibility for its accuracy. He/she then submits the TRA to the CAE and, at the same time, sends an information copy to the DDR&E.

2.3 COMPONENT ACQUISITION EXECUTIVE (CAE)

For ACAT ID and ACAT IAM programs, the CAE submits a report to the DDR&E, with an assessed TRL (or some equivalent measure) for each critical technology. This report can consist of a cover letter or memorandum endorsing the Component TRA and officially transmitting that TRA. This should be accomplished according to the agreed-upon schedule—normally, at least 6 weeks before a scheduled Milestone B or Milestone C. See Figure II-1.

2.4 DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING (DDR&E)

2.4.1 Preparation and Oversight

The DDR&E has both oversight and evaluation responsibilities for the TRA. An AO assists, as directed by the DDR&E (see Figure II-2). While the Component is preparing the TRA, the AO reviews the critical technologies and the identification process, negotiates any perceived deficiencies, and provides oversight. In addition, the AO participates in the TRA to the extent mutually agreed upon with the Component S&T Executive.

2.4.2 Evaluating the Component TRA

The DDR&E evaluates the Component TRA in cooperation with the Component S&T Executive and the PM. There is no rigid requirement that every critical technology has to be at a pre-specified TRL by Milestone B or Milestone C. However, for Milestone B, readiness levels of at least TRL 6 are typical (TRL 7 preferred), and, for Milestone C, readiness levels of at least TRL 8 are typical (TRL 9 preferred). At Milestone B, the DDR&E might conclude that a readiness level of TRL 5 is adequate for a critical technology if there is a planned and funded program in place to mature the technology quickly or if there is a mature backup technology that meets the program requirements and schedule. If the Component expects such a conclusion, the supporting information should be provided along with the TRA. At Milestone C, a similar situation could arise—most likely with respect to the manufacturing process technology required to achieve required production rates or cost goals. Section III of this document addresses TRLs in some detail.

After evaluating the Component TRA, the DDR&E either concurs with the findings or conducts an independent TRA. The DDR&E forwards either a concurrence with the findings of the Component TRA or the findings of the independent TRA to the Overarching Integrated Product Team (OIPT) and the DAB or CIO Review Group. This takes place at least 15 days before a Milestone B or Milestone C decision meeting (see Figure II-1). If this 15-day window is not possible, the date of the decision meeting should be reconsidered so the OIPT and DAB members or CIO Review Group members have ample time to review all the relevant information.

2.4.3 Preparing the National Defense Authorization Act (NDAA) Reports for the Secretary of Defense

SEC. 804 of the NDAA for Fiscal Year 2002, Conference Report, requires the Secretary of Defense to submit reports on the implementation of the DoD technology readiness policy. The DDR&E is responsible for preparing these reports. Paragraph 2.7 describes the responsibilities and procedures in more detail.

2.5 CHAIRMAN, OVERARCHING INTEGRATED PRODUCT TEAM (OIPT)

The OIPT [or, in the case of an ACAT IAM program, the Information Technology Overarching Integrated Product Team (IT OIPT)] is led by the appropriate OSD office. It is composed of

- The PM
- The PEO
- The representatives of the Component staff, the USD(AT&L) staff, the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD(C3I)) staff, and the Joint Staff
- Other OSD principals involved in the oversight and review of a particular ACAT ID or ACAT IAM program.

The OIPT or IT OIPT provides strategic guidance for the early resolution of issues and conducts oversight and review as a program proceeds through its acquisition life cycle.

2.6 MILESTONE DECISION AUTHORITY (MDA)

The MDA is the individual designated in accordance with criteria established by the USD(AT&L)—or the ASD(C3I) for Automated Information System (AIS) acquisition programs—to approve the entry of an acquisition program into the next phase. The DAB or CIO Review Group provides a recommendation to assist the MDA in the decision.

2.7 SECRETARY OF DEFENSE

For each of the calendar years 2002 through 2005, the Secretary of Defense is required to report to Congress on the implementation of DoD policy regarding technology maturity at the initiation of MDAPs.[15] According to SEC. 804 of the NDAA for Fiscal Year 2002, Conference Report, the reports must

> identify each case in which a major Defense acquisition program entered system development and demonstration [i.e., passed MS B (Milestone B)] during the preceding calendar year and into which key technology has been incorporated that does not meet the technological maturity requirement [i.e., that technology must have been demonstrated in a relevant environment or, preferably, in an operational environment, to be considered mature enough to use for product development in systems integration] described in subsection (a) and provide a justification for why such technology was incorporated; and
>
> identify any determination of technological maturity with which the Deputy Under Secretary of Defense for Science and Technology[16] did not concur and explain how the issue has been or will be resolved.

The report for each calendar year must be submitted to the Committees on Armed Services of the Senate and the House of Representatives by March 1 of the following year (i.e., March 1 of years 2003 through 2006).

At the conclusion of each MDAP milestone review, an office designated by the DDR&E will compile the necessary information for these reports. At the beginning of each calendar year (2003 through 2006), the designated office will prepare the report for the Congressional committees. The DDR&E will submit the report to the USD(AT&L) for concurrence and forwarding to the immediate office of the Secretary of Defense. The Secretary of Defense will sign the report or cover letter and submit it to the Congressional committees as required.

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15 This requirement is contained in SEC. 804 of the NDAA for Fiscal Year 2002, Conference Report. Appendix C of this document contains the complete text. The policy to which the Conference Report refers is in the then-current DoDI 5000.2, paragraph 4.7.3.2.2.2.

16 In light of a more recent agreement, DDR&E should bear this responsibility.

III. TRL DEFINITIONS

The *Interim Guidebook* establishes technology maturity expressed in TRLs as the centerpiece for the TRAs required for ACAT ID and ACAT IAM programs. Other means to accomplish a TRA are allowed but should be coordinated in advance by the DDR&E.

It is important to have a strong grasp of the TRL concept. The tables in this section give the TRL fundamentals.

Using TRLs to describe the maturity of technologies considered for use in a new system originated with NASA in the early 1980s. The levels ran from the earliest stages of scientific investigation (level 1) to successful use in a system (level 9), which equates to space flight for NASA. DoD has adopted the NASA definitions—with only minor modifications—for the nine TRLs.

Table III-1 defines and describes the DoD TRL levels. It also lists typical documentation that should be extracted or referenced to support a TRL assignment. Table III-2 includes a set of additional definitions that help provide a uniform interpretation of the levels.

Software is likely to be an important element in many TRAs. Since the TRL definitions in Table III-1 reflect a systems approach in which software is treated as a part of a component or system, software TRLs are not spelled out specifically in these definitions. However, because some guidelines would be useful in determining the TRLs of the software parts of components and systems, Table III-3 provides a set of software TRL definitions developed by the Army.[17]

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[17] According to the *Interim Guidebook*, dated October 30, 2002, the matrix in Appendix 6 (of the *Interim Guidebook*) that describes the TRLs "lists the various technology readiness levels and descriptions from a systems approach for both HARDWARE and SOFTWARE. DoD Components may provide additional clarifications for Software."

Table III-1. TRL Definitions, Descriptions, and Supporting Information (Source: *Interim Guidebook*, dated October 30, 2002)

TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who, where, and when these tests and comparisons were performed.
4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and results from testing laboratory-scale breadboard(s). References to who did this work and when. Provide an estimate of how breadboard hardware and test results differ from the expected system goals.
5	Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.	Results from testing a laboratory breadboard system that are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to match more nearly the expected system goals?

Table III-1. TRL Definitions, Descriptions, and Supporting Information (Source: *Interim Guidebook*, dated October 30, 2002) (Continued)

TRL	Definition	Description	Supporting Information
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
7	System prototype demonstration in an operational environment	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
8	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include Developmental Test and Evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
9	Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in Operational Test and Evaluation (OT&E). Examples include using the system under operational mission conditions.	OT&E reports.

Table III-2. Additional Definitions of TRL Descriptive Terms (Source: *Interim Guidebook*, dated October 30, 2002)

Term	Definition
Breadboard	Integrated components that provide a representation of a system/subsystem and that can be used to determine concept feasibility and to develop technical data. Typically configured for laboratory use to demonstrate the technical principles of immediate interest. May resemble final system/subsystem in function only.
High Fidelity	Addresses form, fit, and function. High-fidelity laboratory environment would involve testing with equipment that can simulate and validate all system specifications within a laboratory setting.
Low Fidelity	A representative of the component or system that has limited ability to provide anything but first-order information about the end product. Low-fidelity assessments are used to provide trend analysis.
Model	A functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.
Operational Environment	Environment that addresses all the operational requirements and specifications required of the final system to include platform/packaging.
Prototype	A physical or virtual model used to evaluate the technical or manufacturing feasibility or military utility of a particular technology or process, concept, end item, or system.
Relevant Environment	Testing environment that simulates the key aspects of the operational environment.
Simulated Operational Environment	Either (1) a real environment that can simulate all of the operational requirements and specifications required of the final system or (2) a simulated environment that allows for testing of a virtual prototype; used in either case to determine whether a developmental system meets the operational requirements and specifications of the final system.

Table III-3. Army Software TRL Definitions

TRL	Definition	Description
1	**SW**: Functionality conjectural	Lowest level of software readiness. Basic research begins to be translated into applied R&D. Examples might include a concept that can be implemented in software or in analytical studies of an algorithm's basic properties.
2	**SW**: Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications may be speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytical studies.
3	**SW**: Analytical and experimental critical functions and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies to produce code that validates the analytical predictions of separate software elements. Examples include software components that are not yet integrated or representative but satisfy an operational need and algorithms run on a surrogate processor in a laboratory environment.
4	**SW:** Functionality demonstrated in a laboratory environment	Basic software components are integrated to establish that they will work together. They are relatively primitive with regard to efficiency and reliability compared with the eventual system. System software architecture development is initiated to include interoperability, reliability, maintainability, extensibility, scalability, and security issues. Software is integrated with simulated current/legacy elements as appropriate.
5	**SW:** Functionality and performance demonstrated in a relevant environment	Reliability of the software ensemble increases significantly. The basic software components are integrated with reasonably realistic supporting elements so that the software can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of software components. System software architecture is established. Algorithms are run on a processor(s) that has characteristics expected in the operational environment. Software releases are "Alpha" versions, and configuration control is initiated. Verification, Validation, and Accreditation (VV&A) is initiated.

Table III-3. Army Software TRL Definitions (Continued)

TRL	Definition	Description
6	**SW:** Functionality and performance demonstrated in a realistic simulated (live/virtual) operational environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in software-demonstrated readiness. Examples include testing a prototype in a live/virtual experiment or in simulated operational environment. Algorithm is run on a processor or in the simulated operational environment. Software releases are “Beta” versions and are configuration controlled. Software support structure in development. VV&A in process.
7	**SW:** Functionality and performance demonstrated in an operational test environment	Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as a command post or air/ground vehicle. Algorithms are run on processor of the operational environment integrated with actual external entities. Software support structure in place. Software releases are in distinct versions (e.g., Version 2.0). Frequency and severity of software deficiency reports do not significantly degrade functionality or performance. VV&A completed.
8	**SW:** Functionality, performance, and quality attributes validated in an operational environment	Software has been demonstrated to work in its final form and under expected conditions. In most cases, this TRL represents the end of system development. Examples include test and evaluation (T&E) of the software in its intended system to determine whether it meets design specifications. Software releases are production versions and are configuration controlled in a secure environment. Software deficiencies are resolved rapidly through the support structure.
9	**SW:** Functionality, performance, and quality attributes proven in an operational environment through successive, successful accomplishment of mission operations	Actual application of the software in its final form and under mission conditions, such as those encountered in OT&E. In almost all cases, this is the end of the last "bug fixing" aspects of system development. Examples include using the system under operational mission conditions. Software releases are production versions and are configuration controlled. Frequency and severity of software deficiencies are at a minimum.

IV. THE TRA PROCESS

4.1 ACTION SEQUENCE FOR A TRA

Attachment 2 includes a description of activities that occur before Milestone A. A collaborative effort produces an ICD that describes the requisite capabilities and time phased, operational goals.[18] The analyses that lead to the ICD identify a preferred concept to be refined after a Milestone A decision.

Figure IV-1 graphically portrays the steps normally anticipated by the DDR&E in the assessment of technology readiness for an ACAT I Milestone review. These steps are derived from information in the *Interim Guidebook*; however, the information in the guidebook is not mandatory. The steps[19] are as follows:

A. During Concept and Technology Development (CTD), the PM or Project Leader[20] develops a system concept and a concept of operation. A functional analysis establishes the functions and performance levels necessary to meet the needs expressed in a Mission Needs Statement (MNS). For the system, the PM or Project Leader develops an Acquisition Program Baseline (APB) and a Work Breakdown Structure (WBS) and conducts a risk assessment, which includes technology risk. Technology choices will be made on the basis of risk, cost, and other factors. If some technologies are not sufficiently mature to support a Milestone B decision, a Technology Development program to be completed before Milestone B is planned. This can be documented in a Technology Development strategy that shows how the program expects to meet the technology readiness requirements for Milestone B.

B. From the WBS, the risk assessment, and functional analysis, the PM identifies those technologies that are not already fully mature but that are critical to the accomplishment of goals for program cost and schedule and for system producibility, cost, and operational effectiveness. These will be listed as *critical technologies*.

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[18] *Attachment 2*, paragraphs 3.2 and 3.4.

[19] The steps that follow (A–J) are marked accordingly in Figure IV-1.

[20] A PM must be assigned before Milestone B; however, during much of the preceding phase, a Project Leader might be leading the activities.

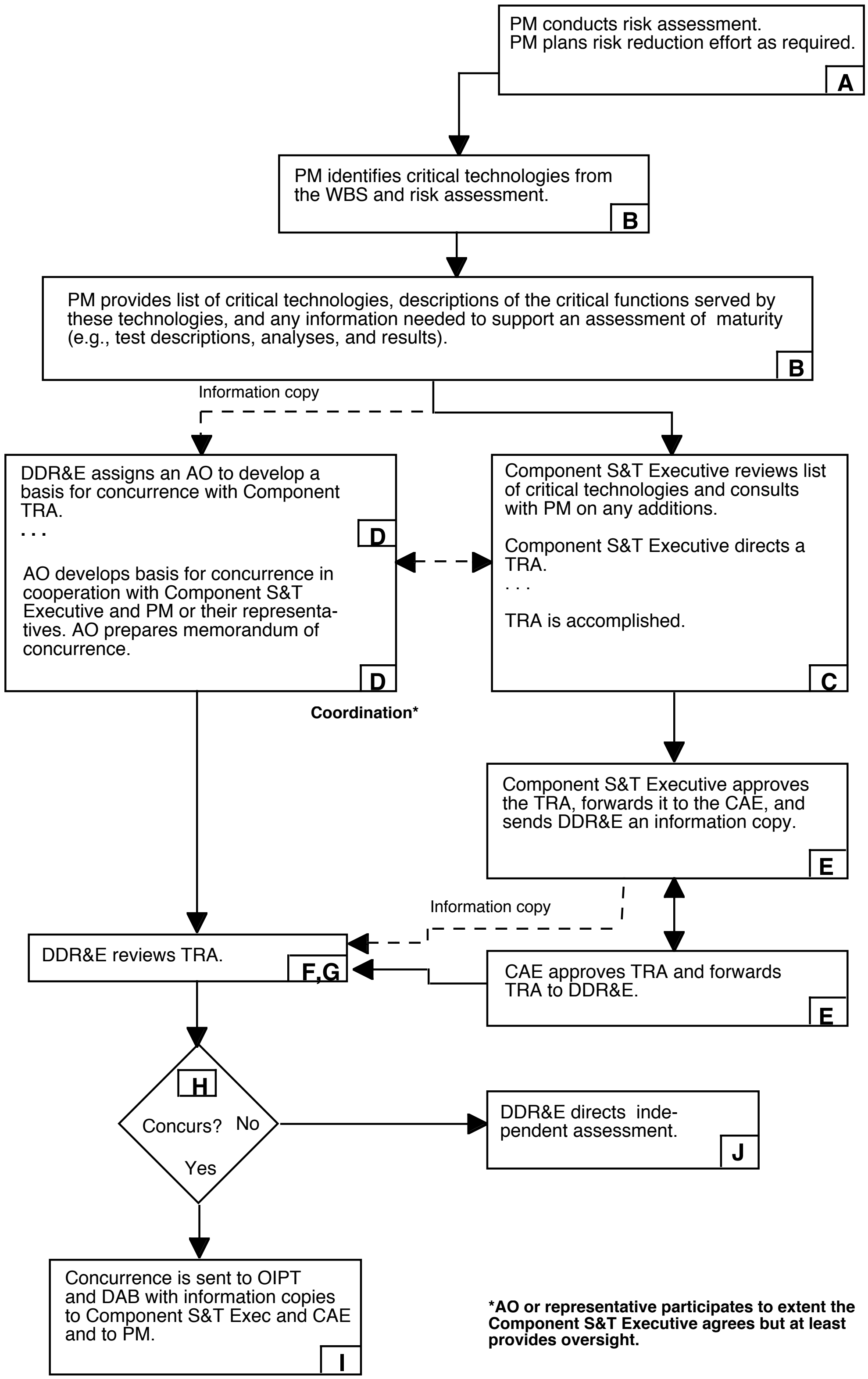

Figure IV-1. Flow Diagram for the TRA Process

To support the TRA required before an upcoming Milestone B or Milestone C, the PM prepares a list of the critical technologies and a maturity assessment of each critical technology. Substantiating information normally consists of descriptions of the status of components or subsystems, the testing that has been accomplished, and the results of this testing. Test environments and results are described in relation to the functional needs of the system concept. At least 16 weeks before a scheduled Milestone B or Milestone C (see Figure II-1), the list of critical technologies and the supporting information are sent to the Component S&T Executive, with a request for a TRA. At the same time, an information copy is sent to the DDR&E.

C. The Component S&T Executive coordinates with the PM on any additions to the list of critical technologies and on any additional information needed for the TRA.

The Component S&T Executive directs and schedules the accomplishment of a TRA based on the PM's request and submission of the critical technologies information.

The TRA is conducted in accordance with Component guidelines and procedures.

D. The DDR&E normally appoints a member of his/her staff to act as AO to develop a basis for the DDR&E to concur with the Component TRA. This basis must be sufficient to fulfill the DDR&E oversight responsibilities, but it should not be a duplication of the Component TRA.

The AO should review the critical technologies and the identification process, negotiate any perceived deficiencies, and provide oversight while the Component TRA is conducted. The AO should coordinate with the Component S&T Executive to determine to what extent the AO or technology specialists of the DDR&E staff could or should monitor or participate in the Component TRA. The Component S&T Executive is not required to agree to any such monitoring or participation beyond oversight.

E. When the Component TRA is completed, the Component S&T Executive approves it and forwards it to the CAE. At the same time, the Component S&T Executive sends an information copy to the DDR&E.

Subsequently, the CAE forwards the approved TRA to the DDR&E.

F. The AO develops a basis for DDR&E concurrence. The approach can be tailored to the specific situation (see paragraph 4.2, which describes one approach). The AO should minimize the impact on the PM and the Component S&T organization but still provide a sound basis for DDR&E concurrence. Monitoring or participating in the Component TRA will likely facilitate a quick concurrence. If the AO deems any critical technology to be insufficiently mature for the coming milestone, he/she tells the Component S&T Executive and the PM so that all involved have an opportunity to reach agreement on appropriate action.

G. Upon receiving the report and official TRA from the CAE, the AO confirms that it is consistent with the information copy.

H. The AO prepares a memorandum of concurrence or nonconcurrence for signature, presents the staff evaluation of the TRA to the DDR&E, provides whatever backup information is needed, and acts on the DDR&E's decision.

I. If the DDR&E concurs, the concurrence memorandum is transmitted to the OIPT and the DAB or to the IT OIPT and CIO Review Group. This must occur at least 2 weeks before the milestone meeting.

J. If the DDR&E does not concur, an independent assessment is required. The AO recommends a course of action and prepares a memorandum directing this action. The independent assessment should be a positive contribution to the acquisition program. For example, it could result in a revised, more realistic schedule, in the use of an alternative technology, or in a revised, evolutionary acquisition strategy. The independent assessment should be conducted as quickly as possible—whether this requires 1 day or several months. Typically, the Component funds the independent assessment.

Paragraph 4.2 offers an approach to developing the basis for DDR&E concurrence.

4.2 DDR&E CONCURRENCE

The DDR&E is required to evaluate the Component TRA before Milestone B and Milestone C of ACAT ID and ACAT IAM programs. An AO, designated by the DDR&E, will normally lead the evaluation effort.

It is recommended that the AO secure DDR&E concurrence as follows:

- When the DDR&E designates an AO, the DDR&E sends a memorandum to the Directors of his/her staff. This memorandum alerts them to a possible need to provide assistance in their respective technology areas and requests them to designate a point of contact (POC) within their Directorates.
- The AO provides copies of the Component TRA to the designated POCs and invites comments by a certain date.
- The AO reviews the TRA and calls for assistance, as necessary, to obtain a competent assessment of the critical technologies or to determine whether all the critical technologies have been identified.

- If a disagreement with the Component TRA emerges, this is noted in a memorandum to the DDR&E. If the disagreement would jeopardize a favorable decision by the USD(AT&L) or the ASD(C3I), the AO obtains a full explanation (and concurrence with the memorandum) from the cognizant Director.
- The AO conveys the evaluation results to the DDR&E in a briefing or memorandum. Key Directors attend or coordinate.
- If the DDR&E does not concur with the Component TRA, the AO prepares the action memorandum to conduct an independent TRA.
- The AO prepares a memorandum for DDR&E signature. This memorandum gives the evaluation results of the Component TRA and the independent TRA, if conducted. It is sent to the Chairman of the OIPT or IT OIPT and to the Executive Secretary of the DAB or the appropriate staff officer of the ASD(C3I).

V. SUBMITTING A TRA

5.1 SKELETAL TEMPLATE FOR A TRA SUBMISSION

The following outline is a skeletal template for anticipated TRA submissions:

1.0 Purpose of This Document

2.0 Program Overview

2.1 Program Objective

2.2 Program Description

2.3 System Description

3.0 Technology Readiness Assessment

3.1 Process Description

3.2 Critical Technologies

3.3 Assessment of Maturity

3.3.1 First Critical Technology or Category of Technology

3.3.2 Next Critical Technology or Category of Technology

3.4 Summary of TRLs by Technology

4.0 Conclusion

5.2 ANNOTATED TEMPLATE FOR A TRA SUBMISSION

The following outline is an annotated version of the TRA template.

1.0 Purpose of This Document

Should be short and should give the program name, the system name if different from the program name, and the milestone or other decision point for which the TRA was performed. For example, "This document presents an independent Technology Readiness Assessment (TRA) for the UH-60M helicopter program in support of the Milestone B decision. The TRA was performed at the direction of the Army S&T Executive."

2.0 Program Overview

2.1 Program Objective

States what the program is trying to achieve (e.g., new capability, improved capability, lower procurement cost, reduced maintenance or manning, and so forth). Refer to the MNS or Operational Requirements Document (ORD) that states the need for this capability.

2.2 Program Description

Describes the program, not the system. Does the program provide a new system or a modification to an existing operational system? Is it an evolutionary acquisition program? What capabilities will be realized in Block 1? When is IOC? Does it have multiple competing prime contractors? Into what architecture does it fit? Is it a system-of-systems? Does its success depend on the success of other acquisition programs?

2.3 System Description

Describes the overall system, the major subsystems, and components, as necessary, to give an understanding of what is being developed and to show what is new, unique, or special about it. Should include the systems, components, and technologies that will later be declared "critical technologies." Describes how the system works (if this is not obvious).

3.0 Technology Readiness Assessment

3.1 Process Description

Tells who led the TRA and what organizations or individuals performed the TRA. Identifies the special expertise of participating organizations or individuals. This should establish the competence and the independence of the TRA. In this context, "independence" means that the assessors are not unduly influenced by the opinions of the developers (government or industry). Usually, the PM or the System Program Office (SPO) will provide most of the data and other information that form the basis of a TRA. Nevertheless, the *assessment* should be *independent* of the PM or SPO.

States the analyses and investigations that were performed when making the assessment (e.g., examination of test setups, discussions with test personnel, analysis of test data, review of related technology, and so forth).

This is only a broad description of the process. Paragraph 3.3 presents an opportunity to include more detail.

3.2 Critical Technologies

Lists the technologies included in the TRA. A table that lists the technology name and includes a few words that describe the technology and its function is appropriate. The technologies can be organized according to the WBS, as provided by the PM. The names of these critical technologies should be used consistently throughout the remainder of the document.

The PM should identify the critical technologies. The Component S&T Executive should assess at least these technologies; however, other technologies that the Component S&T Executive considers critical can also be included.

3.3 Assessment of Maturity

3.3.1 First Critical Technology or Category of Technology

Describes the technology (subsystem, component, or technology). Describes the function it performs and, if needed, how it relates to other parts of the system. Provides a synopsis of Technology Development history and status. This can include facts about related uses of the same or similar technology, numbers or hours of testing of breadboards, numbers of prototypes built and tested, relevance of the test conditions, and results achieved. Finally, applies the criteria for TRLs and assigns a readiness level to the technology. States the readiness level (e.g., TRL 5) and the rationale for choosing this readiness level.

For a complex system, if the critical technologies presented are in categories (e.g., airframe or sensors), the information specified in the previous paragraph (e.g., describing the technology, describing the function it performs, and so forth) should be provided for each critical technology within a category.

3.3.2 Next Critical Technology or Category of Technology

Assessments of the maturity of other critical technologies should present the same information as that in paragraph 3.3.1.

3.4 Summary of TRLs by Technology

Presents a table that lists critical technologies and assesses the TRL of each technology.

4.0 Conclusion

States the Component S&T Executive's position concerning the maturity of the technologies and whether this maturity is adequate for the system to enter the next stage of development. If the position is supportive of entering the next stage even though some critical technologies are less mature than would ordinarily be expected, explains what circumstances or planned work justifies the positive position.

The TRA should be signed "Approved By" the Component S&T Executive, or it should be transmitted with a cover memorandum that clearly states that the TRA presents the position of the Component S&T Executive. In effect, the Component S&T Executive must certify that he/she stands behind the statements in the Conclusion.

GLOSSARY

ACAT	Acquisition Category
AIS	Automated Information System
AO	Action Officer
APB	Acquisition Program Baseline
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
CAE	Component Acquisition Executive
CDD	Capability Development Document
CDR	Critical Design Review
CIO	Chief Information Officer
CTD	Concept and Technology Development
DAB	Defense Acquisition Board
DAS	Defense Acquisition System
DDR&E	Director of Defense Research and Engineering
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DT&E	Developmental Test and Evaluation
DUSD(S&T)	Deputy Under Secretary of Defense for Science and Technology
EDM	engineering development model
FOC	full operational capability
FRP	full-rate production
GAO	Government Accounting Office
ICD	Initial Capabilities Document
IOC	initial operational capability
IOT&E	Initial Operational Test and Evaluation
IT OIPT	Information Technology Overarching Integrated Product Team
LFT&E	Live Fire Test and Evaluation
LRIP	low rate initial production
MAIS	Major Automated Information System
MDA	Milestone Decision Authority

MDAP	Major Defense Acquisition Program
MNS	Mission Needs Statement
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
ODDR&E	Office of the Director of Defense Research and Engineering
OIPT	Overarching Integrated Product Team
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
PEO	Program Executive Officer
PM	Program Manager
POC	Point of Contact
R&D	research and development
S&T	Science and Technology
SDD	System Development and Demonstration
SPO	System Program Office
T&E	test and evaluation
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
VCJCS	Vice Chairman of the Joint Chiefs of Staff
VV&A	Verification, Validation, and Accreditation
WBS	Work Breakdown Structure

APPENDIXES FOR THE TECHNOLOGY READINESS ASSESSMENT (TRA) DESKBOOK

APPENDIX A
SUMMARY OF GENERAL ACCOUNTING OFFICE (GAO) REPORTS AND DEPARTMENT OF DEFENSE (DoD) IMPLEMENTATION

Several GAO reports addressed the DoD acquisition system and made recommendations that influenced the DoD 5000 series of publications and more recent policy statements on Defense acquisition policy. In particular, these reports influenced the involvement of the Component Science and Technology (S&T) communities on the acquisition review process and the use of Technology Readiness Assessments (TRAs).

The following presents a brief summary of GAO-related work, along with references for the source documents.

A.1 GAO REPORTS

The subcommittee on Readiness and Management Support of the Committee on Armed Services, U.S. Senate, which has oversight on acquisitions policy, enlisted the GAO in a study of best commercial practices as related to Defense acquisition. A series of GAO reports and related testimony assessed how best commercial practices could improve the way that DoD incorporates new technology into weapon system programs and reduces risk. These GAO reports, issued from 1996–2000 (the principals of which are listed as References 1, 2, and 3), offered DoD some guidance and, in calendar year 2001 and the first part of 2002, resulted in many changes in the DoD 5000 series of documents. [Department of Defense Directive (DoDD) 5000.1, Department of Defense Instruction (DoDI) 5000.2, and DoD 5000.2-R] (Refs. 4, 5, 6). Recent interim guidance (Ref. 7) on Defense acquisition policy issued by the Under Secretary of Defense similarly reflects attention to the findings and recommendations in the GAO reports.

Figure A-1 illustrates the weapon system acquisition cycle for DoD major weapon systems before References 4, 5, and 6 were issued. Technology, design, and manufacturing knowledge was obtained concurrently.

The major GAO recommendation that followed best commercial practice was to minimize Technology development during product development and match requirements with technological capability before product development is launched. Proof that the technology will work and that it can be demonstrated to a high level of maturity is critical to lowering risk and avoiding large cost overruns. Associated with this principle are the needs to develop high standards for finding the maturity and readiness of technology, to establish disciplined paths that technology must take to be included in products, and to provide strong gatekeepers to decide when to allow the technology into a product development program. GAO recommended that DoD not launch a program until the technologies needed

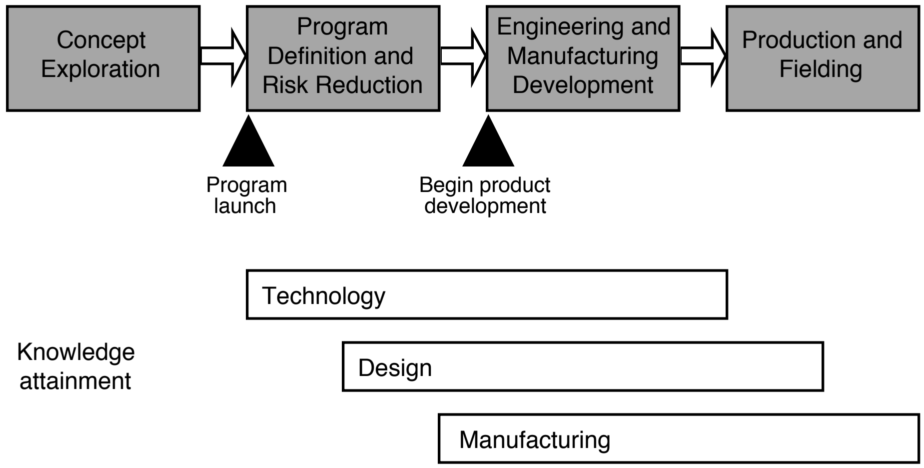

Figure A-1. DoD's Earlier Weapon System Acquisition Cycle

to meet a new weapons requirement are mature. To separate this Technology Development from the program, GAO best commercial practices recommendations suggest that a technology and concept maturation phase follow concept exploration and precede program launch, as illustrated in Figure A-2.

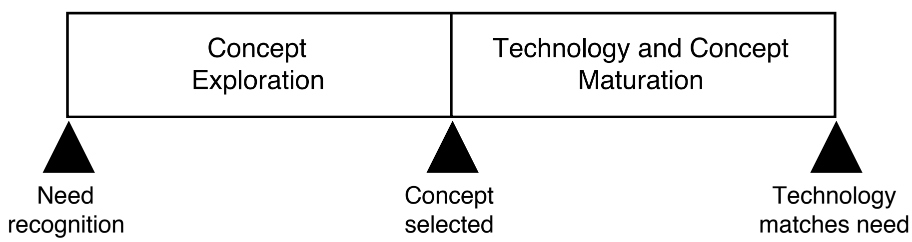

Figure A-2. Weapon Acquisition Phases That Should Precede the Launch of a New Program

The GAO review of best practices for including new technology in products (see Ref. 2) applied a scale of Technology Readiness Levels (TRLs) pioneered by the National Aeronautics and Space Administration (NASA) and adapted by the Air Force Research Laboratory (AFRL). "TRLs proved to be reliable indicators of the relative maturity of the 23 technologies reviewed, both commercial and military, and their eventual success after they were included in product development programs" (Ref. 2, p. 22).

To show that the design is mature, the GAO studies suggest that a product development phase should include a distinct system integration effort *before* the system demonstration effort to demonstrate the effectiveness of the product and processes. See Figure A-3.

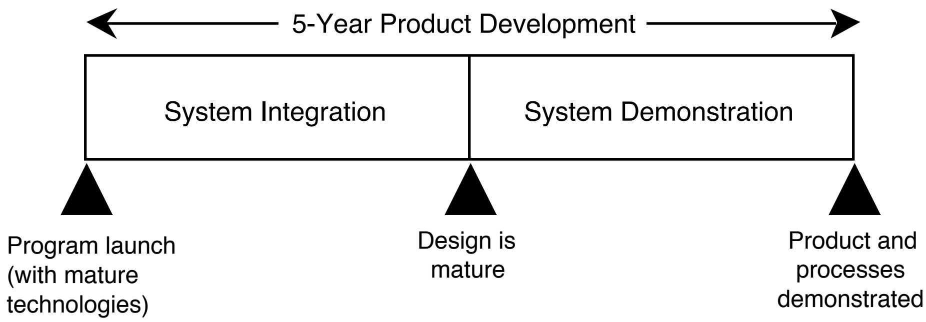

Figure A-3. Product Development Phase To Deliver a Mature Design and Key Processes

Figure A-4 shows GAO's final proposal for a potential DoD technology and product development process based on best commercial practices. It should be noted that leading commercial firms launch a new product later than DoD (i.e., after technology is complete). Paragraphs A.2 and A.3 of this appendix provide the GAO recommendations for DoD management of Technology Development and the DoD response as reported in Reference 2. DoD did not agree entirely with GAO's recommendations and was willing to accept more risk. DoD considered TRL 6 an acceptable readiness-level risk for a weapon system entering the program definition stage (see Figure A-1) and TRL 7 an acceptable readiness-level risk for the Engineering and Manufacturing Development (EMD) stage. GAO accepted this.

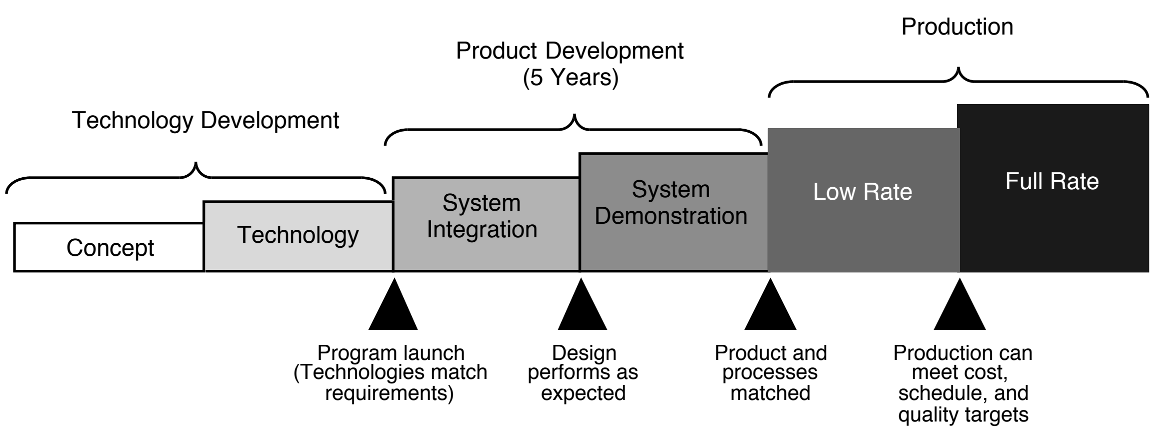

Figure A-4. Potential DoD Technology and Product Development Process Incorporating Best Practices

Figure A-5 shows the process initially proposed by the Office of the Secretary of Defense (OSD) TRA Policy Working Group for accomplishing a TRA.[1] This would occur before Milestone B and Milestone C.

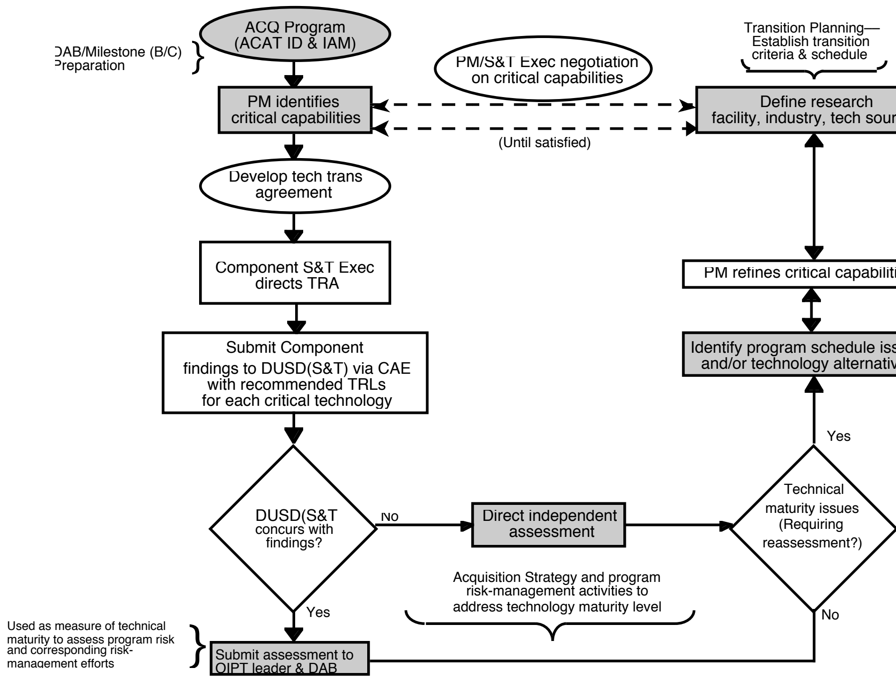

Figure A-5. Proposed TRA Process

Figure A-6 outlines the associated Defense Acquisition Management Framework presented in DoD 5000.2-R.

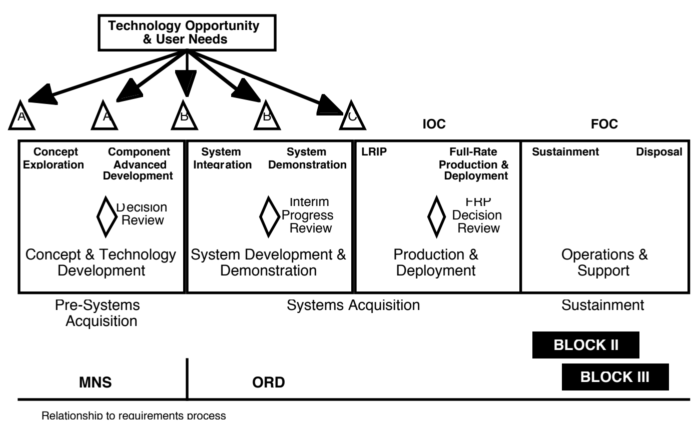

Figure A-6. Defense Acquisition Management Framework

1 This is in the context of the acquisition process established by DoDI 5000.2, 4 January 2001.

A.2 GAO RECOMMENDATIONS

The following paragraphs are direct quotations from Reference 2: GAO/NSIAD-99-162, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*.

> We have previously recommended that DOD separate Technology Development from weapon system programs. That recommendation was made without prejudice toward the necessity of Technology Development but rather with the intent that programs could be better managed if such development was conducted outside of a program manager's purview. Similarly, the recommendations that follow are made without prejudice toward-or the intention of compromising-the basic research and other activities that S&T organizations perform. We recognize that implementation of these recommendations will have organizational, funding, and process implications and will require the cooperation of the Congress (p. 62).
>
> To help ensure that new technologies are vigorously pursued and successfully moved into weapon system programs, we recommend that the Secretary of Defense adopt a disciplined and knowledge-based method for assessing technology maturity, such as TRLs, DOD-wide. This practice should employ standards for assessing risks of handoff to program managers that are based on a technology's level of demonstration and its criticality to meeting the weapon system's requirements (p.63).
>
> With these tools in hand, we recommend that the Secretary (1) establish the place at which a match is achieved between key technologies and weapon system requirements as the proper time for committing to the cost, schedule, and performance baseline for developing and producing that weapon system and (2) require that key technologies reach a high maturity level—analogous to TRL 7-before making that commitment. This would approximate the launch point for product development as practiced by leading commercial firms (p. 63).
>
> We recommend that the Secretary find ways to ensure that the managers responsible for maturing the technologies and designing weapon systems before product development are provided the more flexible environment that is suitable for the discovery of knowledge, as distinct from the delivery of a product. Providing more flexibility will require the cooperation of requirements managers and resource managers so that rigid requirements or the threat of jeopardizing the funding planned to start product development will not put pressure on program managers to accept immature technologies. Such an environment may not be feasible if the program definition and risk reduction phase remains the effective launch point for an entire weapon system program (p. 63).
>
> An implication of these recommendations is that S&T organizations will have to play a greater role in maturing technologies to higher levels and should be funded accordingly. Therefore, we recommend that the Secretary of Defense evaluate the different ways S&T organizations can play a greater role in helping technologies reach high levels of maturity before product

development begins. For example, given that a technology has sufficient potential for application to a weapon system, at a minimum, an S&T organization should be responsible for taking a technology to TRL 6 before it is handed off to a program office at the program definition and risk reduction phase. During this phase, the program manager would be responsible for maturing the technology to TRL 7 before it is included in an engineering and manufacturing development program. In a situation where a single, design-pacing technology is to be developed for a known application—like the nonpenetrating periscope—an S&T organization should be required to mature that technology to TRL 7 before it is turned over to a product development manager. S&T organizations could play a similar role when a significant new technology is being prepared for insertion into an existing weapon system. Finally, when multiple new technologies are to be merged to create a weapon system, S&T organizations should be required to bring key technologies to TRL 6 and then become part of a hybrid organization with product developers to integrate the technologies and bring them to TRL 7 before handing full responsibility to a product development manager (pp. 63–64).

To help guard against the possibility that the more basic research and Technology Development activities would be compromised by having S&T organizations routinely take key technologies to TRL 6 or higher, we recommend that the Secretary extract lessons from the nonpenetrating periscope, the AAAV, and the Army's Future Scout programs, and other ATD and ACTD programs. Specifically, the Secretary should assess whether the resources needed to enable S&T organizations to play a leading role in the development of technologies and, in some cases, preliminary system design, detracted from or displaced more basic research and Technology Development programs (p. 64).

Finally, we recommend that the Secretary empower managers of product development programs to refuse to accept key technologies with low levels of demonstrated maturity. The Secretary can encourage this behavior through supportive decisions on individual programs, such as by denying proposals to defer the development of key technologies and by favoring proposals to lengthen schedules or lessen requirements to reduce technological risk early (p. 64).

A.3 DoD COMMENTS AND GAO EVALUATION

The following paragraphs are direct quotations from Reference 2: GAO/NSIAD-99-162, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*.

DOD generally concurred with a draft of this report and its recommendations, noting that the traditional path to new weapon system development is no longer affordable or necessary (see app. I). DOD stated that it has embarked upon a "Revolution in Business Affairs" that will enable new technologies to be developed more efficiently and effectively. It believes that the first steps in this direction have already been taken but agrees that more progress needs to be made. DOD agreed that TRLs are necessary in assisting decision-makers in deciding on when and where to insert new technologies into weapon system programs and that weapon system managers should ensure that technology is matured to a TRL 7 before insertion occurs. DOD concurred that S&T organizations should be involved in maturing technologies to high levels, such as TRL 6, before transitioning to the engineering and manufacturing development phase and agreed to assess the impact of this involvement on other S&T resources. We note that the best practice is to mature technology to at least a TRL 7 before starting the engineering and manufacturing development phase, whether the technology is managed by an S&T organization, a weapon system program manager, or a hybrid of the two organizations (pp. 64–65).

DOD noted that while TRLs are important and necessary, the increasing projected life for new weapon systems, total ownership costs, and urgency based upon threat assessments are also important considerations for system development decisions. We agree and note that our recommendations are not intended to cover all aspects of weapon system development decisions or to suggest that technology maturity is the only factor in such decisions. Rather, the recommendations are in keeping with the purpose of the report, "to determine whether best practices offer methods to improve the way DOD matures new technology so that it can be assimilated into weapon system programs with less disruption." We believe that a knowledge-based approach to maturing technology, such as TRLs, can benefit other considerations as well. For example, decisions on what technologies to include in a weapon system and when to include them can have a significant bearing on its total ownership costs (p.65).

DOD stated that there should be an established point for the transition of technologies and that it plans to supplement its milestone review process with additional guidance in the next revisions to DOD 5000.2-R. It also stated that its policy on the evolutionary approach to weapon acquisitions should be developed in consonance with the technology transition strategy. We cannot comment on the revisions to the directive or the evolutionary acquisition policy because they have yet to be published. However, under the current milestone review process, the pressures placed on a program during the program definition and risk reduction phase—when much Technology Development occurs—can operate against the flexibility and judgments that are needed to mature technologies. If the revisions to the directive supplement the current milestones without relieving the pressures brought to bear on programs as they are launched in the program definition and risk reduction phase, it will remain difficult to discourage the acceptance of immature technologies in the design of new weapon systems. To relieve these pressures, we encourage DOD, as it develops the directive and the evolutionary acquisition policy, to separate Technology Development from product development and to redefine the launch point for a program as the point at which enough knowledge has been gained to ensure that a match is reached between the maturity of key technologies and weapon system requirements (pp. 65–66).

DOD also stated that program managers already have the ability to reject inappropriately mature technologies, and to the extent technology immaturity affects acquisition baselines, to advise acquisition executives of feasible alternatives. We did not find this to be the case in our review. Rather, we found that the program managers' ability to reject immature technologies is hampered by (1) untradable requirements that force acceptance of technologies despite their immaturity and (2) reliance on tools for judging technology maturity that fail to alert the managers of the high risks that would prompt such a rejection. As noted in the report, once a weapon system program begins, the environment becomes inflexible and deviations to program baselines can attract unwanted attention. This reality limits the program managers' ability to reject immature technologies (p. 66).

A.4 REFERENCES

1. GAO/T-NSIAD 99-116, *Defense Acquisition: Best Commercial Practices Can Improve Program Outcomes*. Statement for the Record by Louis J. Rodrigues, Director, Defense Acquisition Issues, National Security and International Affairs Division. Testimony Before the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate, March 1999.
(See http://www.fas.org/man/gao/nsiad-99-116.htm).

2. GAO/NSIAD-99-162, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*. United States General Accounting Office (GAO) Report to the Chairman and Ranking Minority Member, Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate, July 1999.
(See http://www.fas.org/man/gao/nsiad-99-162.htm).

3. GAO/T-NSIAD-00-137, *Defense Acquisition: Employing Best Practices Can Shape Better Weapon System Decisions*. Statement of David M. Walker, Comptroller General of the United States. Testimony Before the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate, April 26, 2000.
See http://www.gao.gov/archive/2000/ns00137t.pdf).

4. DoDD 5000.1, *The Defense Acquisition System,* 23 October 2000 (Incorporating Change 1, January 4, 2001).

5. DoDI 5000.2, *Operation of the Defense Acquisition System*, (Including Change 1), 4 January 2001.

6. DoD 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAP) and Major Automated Information System (MAIS) Acquisition Programs,* April 5, 2002.

7. Under Secretary of Defense Memorandum, Subject: *Defense Acquisition,* dated October 30, 2002. (See http://dod5000.dau.mil/index.htm).

ACRONYMS FOR APPENDIX A

AAAV	Advanced Amphibious Assault Vehicle
ACAT	Acquisition Category
ACTD	Advanced Concept Technology Demonstration
ACQ	acquisition
AFRL	Air Force Research Laboratory
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
ATD	Advanced Technology Demonstration
CAE	Component Acquisition Executive
DAB	Defense Acquisition Board
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DUSD(S&T)	Deputy Under Secretary of Defense for Science and Technology
EMD	Engineering and Manufacturing Development
FOC	full operational capability
GAO	General Accounting Office
IOC	initial operational capability
LRIP	low rate initial production
MAIS	Major Automated Information System
MDAP	Major Defense Acquisition Program
MNS	Mission Needs Statement
MS	Milestone
NASA	National Aeronautics and Space Administration
NSIAD	National Security and International Affairs Division (GAO)
OIPT	Overarching Integrated Product Team
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
PM	Program Manager
S&T	Science and Technology
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level

APPENDIX B
EXTRACTS FROM POLICY DOCUMENTS RELEVANT TO TECHNOLOGY READINESS ASSESSMENTS (TRAs)

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[1] Deputy Secretary of Defense Memorandum, Subject: *Defense Acquisition*, dated October 30, 2002 has two attachments: *The Defense Acquisition System,* dated October 30, 2002 *(Attachment 1)* and *Operation of the Defense Acquisition System,* dated October 30, 2002 *(Attachment 2)*, referred to in this deskbook as *Attachment 1* and *Attachment 2*. This memorandum and the two attachments are available at http://dod5000.dau.mil/. The *Interim Defense Acquisition Guidebook*, dated October 30, 2002, is also available at http://dod5000.dau.mil/. The reader is reminded that the *Interim Guidebook* has drawn heavily from the former DoD 5000.2-R and retains words that reflect the directive nature of that document. In the preparation of this appendix, no editing was done on the text extracts from the attachments or the guidebook. The *Interim Guidebook* is intended to be helpful assistance for adopting best practices.

B.1 EXTRACTS FROM THE DEPUTY SECRETARY OF DEFENSE MEMORANDUM ATTACHMENTS AND FROM THE *INTERIM GUIDEBOOK* THAT ARE RELEVANT TO TRA PROCEDURES

B.1.1 Extracts From *Attachment 1*

- **Paragraph 3.1**

  – – *Decentralize Responsibility. Responsibility for acquisition of systems shall be decentralized to the maximum extent practicable. A single individual shall be provided sufficient authority to accomplish program objectives for development, production, and sustainment. The Milestone Decision Authority (MDA) shall ensure accountability and maximize credibility in cost, schedule, and performance reporting.*

- **Paragraph 3.2**

  – – *Tailoring. There is no one best way to structure an acquisition program so that it accomplishes the objectives of the Defense Acquisition System. Decision-makers and program managers (PMs) shall tailor various aspects of the acquisition system, including program documentation, acquisition phases, the timing and scope of decision reviews, decision levels, and acquisition strategies to fit the particular conditions of an individual program and minimize the time it takes to satisfy the validated need or exploit the technology opportunity, consistent with common sense, sound business management practice, applicable laws and regulations, and the time-sensitive nature of the user's requirement. MDAs shall promote flexible approaches to oversight and review based on mutual trust and a program's dollar value, risk, and complexity.*

- **Paragraph 3.4**

  – – *Technology Development and Transition. The S&T program shall address user needs; maintain a broad-based program spanning all Defense-relevant sciences and technologies to anticipate future needs and those not being pursued by civil or commercial communities; preserve long-range research; and enable rapid successful transition from the S&T base to useful military products.*

- **Paragraph 3.5**

  – – *Reduced Cycle Time. Advanced technology shall be integrated into producible systems and deployed in the shortest time practicable. Validated, time-phased requirements matched with projected capability needs and available technology support the development of evolutionary acquisition strategies. Evolutionary acquisition strategies shall be the preferred* *approach to satisfying operational needs. Spiral development shall be the preferred process.*

- **Paragraph 3.6**

  – – *Collaboration. The Defense acquisition, requirements, and financial communities shall maintain continuous and effective communications with each other and with the operational user through the use of Integrated Product Teams. Teaming among warfighters, users, developers, acquirers, technologists, industry, testers, budgeters, and sustainers shall begin during requirements definition. PMs and MDAs shall be responsible for making decisions and leading implementation of their programs, and are accountable for results.*

- **Paragraph 3.14**

  – – *Knowledge-Based Acquisition. Knowledge about key aspects of a system shall be demonstrated by the time decisions are to be made. Technology risk shall be reduced and technologies shall have been demonstrated in a relevant environment, with alternatives identified, prior to program initiation. Integration risk shall be reduced and product design demonstrated prior to critical design review. Manufacturing risk shall be reduced and producibility demonstrated prior to full-rate production.*

- **Paragraph 3.16**

  – – *Products, Services, and Technologies. The DoD Component(s) shall consider multiple concepts and analyze possible alternative ways to satisfy the user need. System concepts shall be founded in an operational context, consistent with the National Military Security Strategy, Defense Planning Guidance, and Joint Operating Concepts. DoD Components shall seek the most cost-effective solution over the system's life cycle. They shall conduct market research and analysis to determine the availability, suitability, operational supportability, interoperability, and ease of integration of the considered and selected procurement solutions. The DoD Components shall work with users to define requirements that facilitate, in preferred order, (1) the procurement/modification of commercially available products, services, and technologies, from domestic or international sources, or the development of dual-use technologies; (2) the additional production/modification of previously-developed U.S. and/or Allied military systems or equipment; (3) a cooperative development program with one or more Allied nations; (4) a new joint Component or Government Agency development program; or (5) a new DoD Component-unique development program.*

B.1.2 Extracts From *Attachment 2*

- **Paragraph 3.1.3**

  – – *The tables at Tab C*[2] *identify the statutory and regulatory information requirements of each milestone and decision point. Additional non-mandatory guidance on best practices, lessons learned, and expectations* are available in a guidebook at http://www.acq.osd.mil/ar/.

C.T1. Table 1. Statutory Information Requirements

INFORMATION REQUIRED	APPLICABLE STATUTE	WHEN REQUIRED
Consideration of Technology Issues	10 U.S.C. 2364, reference (g)	Milestone (MS) A MS B MS C
Market Research	10 U.S.C. 2377, reference (j)	Technology Opportunities User Needs MS A MS B
Acquisition Program Baseline (APB)	10 U.S.C. 2435, reference (k)	Program Initiation for Ships MS B MS C (updated, as necessary) Full-Rate Production DR
Program Deviation Report	10 U.S.C. 2435, reference (k)	Immediately upon a program deviation
Compliance with Strategic Plan (as part of the analysis of alternatives, whenever practical)	5 U.S.C. 306, reference (l)	MS B MS C
Selected Acquisition Report (SAR)—DD-AT&L(Q&A)823 (MDAPs only)	10 U.S.C. 2432, reference (m)	Program Initiation for Ships MS B and annually thereafter End of quarter following MS C Full-Rate Production DR Breach
Unit Cost Report (UCR)—DD-AT&L(Q&R)1591 (MDAPs only)	10 U.S.C. 2433, reference (n)	Quarterly
Live Fire Waiver & alternate LFT&E Plan (Covered Systems only)	10 U.S.C. 2366, reference (o)	MS B
Industrial Capabilities (part of acquisition strategy) (N/A for AISs)	10 U.S.C. 2440, reference (p)	MS B MS C
LRIP Quantities (N/A for AISs)	10 U.S.C. 2400, reference (q)	MS B

2 For the reader's convenience, the applicable tables from Tab C of *Attachment 2* (C.T1. Table 1. Statutory Information Requirements and C.T2. Table 2. Regulatory Information Requirements) are included here.

C.T1. Table 1. Statutory Information Requirements (Continued)

INFORMATION REQUIRED	APPLICABLE STATUTE	WHEN REQUIRED
Independent Cost Estimate (CAIG) and Manpower Estimate (reviewed by OUSD(P&R)) (N/A for AISs) (MDAPs Only)	10 U.S.C. 2434, reference (r)	Program Initiation for Ships (cost assessment only) MS B MS C Full-Rate Production DR
Operational Test Plan (DOT&E Oversight Programs only)	10 U.S.C. 2399, reference (g)	Prior to start of operational test and evaluation
Cooperative Opportunities (part of acquisition strategy)	10 U.S.C. 2350a, reference (s)	MS B MS C
Post-Deployment Performance Review	5 U.S.C. 306, reference (l) 40 U.S.C. 1401 <u>et seq</u>., reference (t)	Full-Rate Production DR
Beyond-LRIP Report (OSD OT&E Oversight programs only)	10 U.S.C. 2399, reference (g)	Full-Rate Production DR
LFT&E Report, RCS DD-OT&E(AR)1845 (LFT&E-covered programs only)	10 U.S.C. 2366, reference (o)	Full-Rate Production DR
Electronic Warfare (EW) T&E Report, Report Control Symbol (RCS) DD-AT&L(A)2137 (EW programs on OSD T&E Oversight List)	HR 103-357 (1993), reference (u)	Annually
CCA Compliance (All IT–including NSS) (See Tab C, Table 2)	40 U.S.C. 1401 <u>et seq</u>., reference (t)	Program Initiation for Ships MS B MS C Full-Rate Production DR
Registration of mission-critical and mission-essential information systems, RCS DD-C3I(AR)2096	Pub.L. 106-259, Section 8102, reference (v) (or successor appropriations act provision) Pub.L. 106-398, Section 811, reference (w)	Program Initiation for Ships MS B (if Program Initiation) MS C (if Program Initiation)
Spectrum Certification Compliance (DD Form 1494) (applicable to all systems/equipment that require utilization of the electromagnetic spectrum)	47 U.S.C. 305, reference (x) Pub. L. 102-538, 104, reference (y) 47 U.S.C. 901-904, reference (z) OMB Circular A-11, Part 2, reference (b) DoD Directive 4650.1, reference (aa)	MS B MS C (if no MS B)
Programmatic Environmental Safety and Health Evaluation (Including National Environmental Policy Act Schedule)	42 U.S.C. 4321, reference (aa)	Program Initiation for Ships MS B MS C Full-Rate Production DR
Core Logistics Analysis/Source of Repair Analysis (part of acquisition strategy)	10 U.S.C. 2464, reference (ab) 10 U.S.C. 2460, reference (ac) 10 U.S.C. 2466, reference (ad)	MS B MS C (if no MS B)
Competition Analysis (Depot-level Maintenance $3M rule) (part of acquisition strategy)	10 U.S.C. 2469, reference (ae)	MS B MS C (if no MS B)

C.T2. Table 2. Regulatory Information Requirements

INFORMATION REQUIRED	SOURCE	WHEN REQUIRED
Validated ICD – Validated CDD – Validated CPD –	CJCSI 3170.01, reference (e)	Program Initiation for Ships MS A MS B MS C
Acquisition Strategy	This Memorandum	Program Initiation for Ships MS B MS C Full-Rate Production DR
Analysis of Multiple Concepts	This Memorandum	MS A
Analysis of Alternatives (AoA)	This Memorandum	MS B MS C (if no MS B)
System Threat Assessment (AIS programs use published Capstone Information Operations System Threat Assessment) (validated by DIA for ACAT ID programs)	DoDD 5105.21, reference (af)	MS B MS C
Technology Readiness Assessment	This Memorandum	Program Initiation for Ships (preliminary assessment) MS B MS C
Independent Technology Assessment (ACAT ID only) (if required by DUSD(S&T))	This Memorandum	MS B MS C
C4ISP (also summarized in the acquisition strategy)	DoDD 4630.5 DoDI 4630.8, references (ah) and (ag)	Program Initiation for Ships MS B MS C
C4I Supportability Certification	This Memorandum	Full-Rate Production DR
Interoperability Certification	This Memorandum	Full-Rate Production DR
Affordability Assessment	This Memorandum	MS B MS C
Economic Analysis (MAISs only)	This Memorandum	MS B
Component Cost Analysis (mandatory for MAIS; as requested by CAE for MDAP)	This Memorandum	Program Initiation for Ships MS B (for MAIS, each time the MDA requests an Economic Analysis) Full-Rate Production DR (MDAPs only)
Cost Analysis Requirements Description (MDAPs and MAIS Acquisition Programs only)	This Memorandum	Program Initiation for Ships MS B MS C Full-Rate Production DR
Test and Evaluation Master Plan (TEMP)	This Memorandum	MS A (evaluation strategy only) (w/in 180 days after MS A approval) MS B MS C (update, if necessary) Full-Rate Production DR

C.T2. Table 2. Regulatory Information Requirements (Continued)

INFORMATION REQUIRED	SOURCE	WHEN REQUIRED
Operational Test Activity Report of Operational Test and Evaluation Results	This Memorandum	MS B MS C Full-Rate Production DR
Component Live Fire Test and Evaluation Report (Covered Systems Only)	This Memorandum	Completion of Live Fire Test and Evaluation
Program Protection Plan (PPP) (for programs with critical program information) (also summarized in the acquisition strategy)	DoDD 5200.39, reference (a)	MS B (based on validated requirements in CPD) MS C
Exit Criteria	This Memorandum	Program Initiation for Ships MS A MS B MS C Each Review
Defense Acquisition Executive Summary (DAES), DD-AT&L(Q)1429	This Memorandum	Quarterly Upon POM or BES submission Upon unit cost breach
ADM	This Memorandum	Program Initiation for Ships MS A MS B MS C Each Review

- **Paragraph 3.3**

  – – *3.3.1 Evolutionary acquisition is DoD's preferred strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The success of the strategy depends on the consistent and continuous definition of requirements and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept.*

  – – *3.3.2 The approaches to achieve evolutionary acquisition require collaboration between the user, tester, and developer. They include the following:*

  – – *3.3.2.1 Spiral Development. In this process, a desired capability is identified, but the end-state requirements are not known at program initiation. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation.*

  – – *3.3.2.2 Incremental Development. In this process, a desired capability is identified, an end-state requirement is known, and that requirement is met* *over time by development of several increments, each dependent on available mature technology.*

- **Paragraph 3.4**

  – – *User Needs and Technology Opportunities. The requirements generation and acquisition management systems shall use the integrated architectures and an analysis of doctrine, organization, training, materiel, leadership, personnel, and facilities (DOTMLPF) in an integrated, collaborative process to define desired capabilities to guide the development of systems. The Joint Staff shall lead requirements generation, and all documentation and procedures shall comply with reference (e). Representatives from multiple DoD communities shall assist in the formulation of broad, time-phased, operational goals, and describe requisite capabilities in the Initial Capabilities Document (ICD). They shall examine multiple concepts and alternatives to optimize the way the Department of Defense provides these capabilities. The examination shall include robust analyses that consider affordability, technology maturity, and responsiveness. Technologists and industry shall identify and protect promising technologies in laboratories and research centers, academia, and commercial sources; reduce the risks of introducing these technologies into the acquisition process; and promote coordination, cooperation, and mutual understanding of technology issues. The conduct of Science & Technology (S&T) activities shall not preclude, and where practicable, shall facilitate future competition.*

- **Paragraph 3.5 Concept and Technology Development**

  – – *3.5.1. Purpose. The purpose of this phase is to refine the initial concept and reduce technical risk. Concept and Technology Development has two major efforts: Concept Exploration and Technology Development. The phase begins with a Milestone A decision to enter Concept and Technology Development. At Milestone A, the MDA shall designate a lead DoD Component and approve Concept and Technology Development exit criteria. The leader of the concept development team, working with the integrated test team, shall develop an evaluation strategy that describes how the capabilities in the ICD will be evaluated once the system is developed. A favorable Milestone A decision DOES NOT yet mean that a new acquisition program has been initiated. The tables in Tab C identify all statutory and regulatory requirements applicable to Milestone A.*

  – – *3.5.2. Entrance Criteria. Entrance into this phase depends upon a validated and approved ICD resulting from the analysis of potential concepts across the DoD Components, international systems from Allies, and cooperative opportunities; and an assessment of the critical technologies* *associated with these concepts, including technology maturity, technology risk, and, if necessary, technology maturation and demonstration needs.*

– – *3.5.3. Concept Exploration. Concept Exploration typically consists of competitive, parallel, short-term concept studies guided by the ICD. The focus of these studies is to refine and evaluate the feasibility of alternative solutions to the initial concept, and to provide a basis for assessing the relative merits of these solutions. Analyses of alternatives shall be used to facilitate comparisons. In order to achieve the best possible system solution, emphasis shall be placed on innovation and competition. To this end, participation by a diversified range of businesses should be encouraged. For business applications, the PSA shall consider existing commercial-off-the-shelf functionality and solutions. Concept Exploration ends when the MDA selects the preferred solution to be pursued.*

– – *3.5.4. Technology Development. Technology Development is a continuous technology discovery and development process reflecting close collaboration between the user and the system developer. It is an iterative process designed to assess the viability of technologies while simultaneously refining user requirements.*

– – *3.5.4.1. The project shall enter Technology Development when the project leader has a solution for the needed capability and understands the solution as a part of the integrated architecture and its DOTMLPF implications. Technology Development is intended to reduce technology risk and to determine the appropriate set of technologies to be integrated into a full system. This work effort normally shall be funded only for the advanced development work. Shipbuilding programs may be initiated at the beginning of Technology Development. The information required in the tables at Tab C shall support program initiation. A cost assessment shall be prepared in lieu of an ICE, and a preliminary assessment of the maturity of key technologies shall be provided.*

– – *3.5.4.2. The ICD shall guide this work effort. Multiple Technology Development demonstrations may be necessary before the user and developer agree that a proposed technical solution is affordable, militarily useful, and based on mature technology.*

– – *3.5.4.3. If time-phased requirements are used, the initial capability represents only partial fulfillment of the overall capability described in the ICD, and successive Technology Development efforts shall continue until all capabilities have been satisfied. In a spiral development process, the identification and development of the technologies necessary for follow-on increments continues in parallel with the acquisition of preceding* *increments, allowing the mature technologies to more rapidly proceed into System Development and Demonstration.*

– – *3.5.4.4. The project shall exit Technology Development when an affordable increment of militarily useful capability has been identified, the technology for that increment has been demonstrated in a relevant environment, and a system can be developed for production within a short timeframe (normally less than five years); or when the MDA decides to terminate the effort. During Technology Development, the user shall prepare the Capability Development Document (CDD) to support subsequent program initiation and to refine the integrated architecture. A Milestone B decision follows the completion of Technology Development.*

- **Paragraph 3.6 <u>System Development and Demonstration</u>**

– – *3.6.1 <u>Purpose</u>. The purpose of the System Development and Demonstration phase is to develop a system; reduce integration and manufacturing risk (technical risk reduction occurs during Concept and Technology Development); ensure operational supportability with particular attention to reducing the logistics footprint and providing for human systems integration (working with the personnel, training, environmental, safety, health, and manpower communities); design for producibility; ensure affordability and the protection of Critical Program Information (CPI); and demonstrate system integration, interoperability, and utility. Discovery and development are aided by the use of simulation-based acquisition and test and evaluation integrated into an efficient continuum and guided by a system acquisition strategy and test and evaluation master plan (TEMP). The independent planning, execution, and evaluation of dedicated Initial Operational Test and Evaluation (IOT&E), as required by law, and Follow-on Operational Test and Evaluation (FOT&E), if required, shall be the responsibility of the appropriate operational test activity. A Director, Operational Test & Evaluation (DOT&E)-approved live-fire test and evaluation (LFT&E) strategy shall guide LFT&E activity.*

System Development and Demonstration has two major efforts: System Integration and System Demonstration. The entrance point is Milestone B, which is also the initiation of an acquisition program. There shall be only one Milestone B per program or evolutionary increment. Each increment of an evolutionary acquisition shall have its own Milestone B. The tables in Tab C identify the statutory and regulatory requirements that must be met at Milestone B. For Shipbuilding Programs, the required program information shall be updated in support of the Milestone B decision, and the ICE shall be completed. Technical maturity assessments will consider the risk associated with critical sub-systems prior to ship installation.

Long lead for follow ships may be initially authorized at Milestone B, with final authorization and follow ship approval by the MDA dependent on completion of critical sub-system demonstration and an updated assessment of technical maturity.

– – *3.6.2 Entrance Criteria. Entrance into this phase depends on technology maturity (including software), validated requirements, and funding. Unless some other factor is overriding in its impact, the maturity of the technology shall determine the path to be followed. Programs that enter the acquisition process at Milestone B shall have an integrated architecture for their relevant mission area.*

– – *3.6.2.1 Before proposing a new acquisition program, DoD Components shall affirmatively answer the following questions:*

– – *3.6.2.1.1 Does the acquisition support core/priority mission functions that need to be performed by the Federal Government?*

– – *3.6.2.1.2 Does the acquisition need to be undertaken by the DoD Component because no alternative private sector or governmental source can better support the function?*

– – *3.6.2.1.3 Does the acquisition support work processes that have been simplified or otherwise redesigned to reduce costs, improve effectiveness, and make maximum use of commercial off-the-shelf technology?*

– – *3.6.2.2 The management and mitigation of technological risk, which allows less costly and less time-consuming systems development, is a crucial part of overall program management and is especially relevant to meeting cost and schedule goals. Objective assessment of technology maturity and risk shall be a continuous aspect of Defense acquisition. Technology developed in S&T or procured from industry or other sources shall have been demonstrated in a relevant environment or, preferably, in an operational environment to be considered mature enough to use for product development in systems integration. Technology maturity assessments, and where necessary, independent assessments, shall be conducted. If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs.*

– – *3.6.2.3 Prior to beginning System Development and Demonstration, users shall identify and the requirements authority shall validate a minimum set of key performance parameters (KPPs), included in the CDD, that shall guide the efforts of this phase. These KPPs may be refined as conditions warrant. Each set of KPPs shall only apply to the current increment of capability in development and demonstration (or, in a single step to full capability, to the entire system). At Milestone B, the PM shall* *prepare and the MDA shall approve an acquisition strategy that specifies the approach the program will use to achieve the required capability. Each program shall also have an Acquisition Program Baseline establishing program goals--thresholds and objectives--for the minimum number of cost, schedule, and performance parameters that describe the program over its life cycle.*

– – *3.6.2.4 The affordability determination is made in the process of addressing cost as a military requirement in the requirements process and included in each CDD, using life-cycle cost or, if available, total ownership cost. Transition into System Development and Demonstration also requires full funding (i.e., inclusion of the dollars and manpower needed for all current and future efforts to carry out the acquisition strategy in the budget and out-year program), which shall be programmed when a system concept and design have been selected, a program manager (PM) has been assigned, requirements have been approved, and system-level development is ready to begin. In the case of a replacement system, when the Milestone B is projected to occur in the first 2 years of the Future Years Defense Program under review, the program shall be fully funded in that Planning, Programming, and Budgeting System cycle. In no case shall full funding be done later than Milestone B, unless a program first enters the acquisition process at Milestone C. The DoD Components shall fully fund their share of approved joint and international cooperative program commitments.*

– – *3.6.3 <u>System Integration</u>. This work effort is intended to integrate subsystems and reduce system-level risk. The program shall enter System Integration when the PM has a technical solution for the system, but has not yet integrated the subsystems into a complete system. Validated KPPs shall guide this work effort. This work effort shall typically include the demonstration of prototype articles.*

– – *3.6.4 <u>Proceeding Beyond Critical Design Review</u>. The Critical Design Review during System Development and Demonstration provides an opportunity for mid-phase assessment of design maturity as evidenced by such measures as, for example, the number of completed subsystem and system design reviews; the percentage of drawings completed; adequate development testing; a completed failure modes and effects analysis; the identification of key system characteristics and critical manufacturing processes; and the availability of reliability targets and a growth plan; etc. Successful completion of Critical Design Review ends System Integration and continues System Development and Demonstration into the System Demonstration work effort.*

– – *3.6.5 System Demonstration. This effort is intended to demonstrate the ability of the system to operate in a useful way consistent with the validated KPPs. The program shall enter System Demonstration when the PM has demonstrated the system in prototypes. This work effort shall end when a system is demonstrated in its intended environment, using engineering development models or integrated commercial items; meets validated requirements; industrial capabilities are reasonably available; and the system meets or exceeds exit criteria and Milestone C entrance requirements. Successful development test and evaluation, early operational assessments, and, where proven capabilities exist, the use of modeling and simulation to demonstrate system integration are critical during this work effort. The completion of this phase is dependent on a decision by the MDA to commit to the program at Milestone C or a decision to end this effort.*

ATTACHMENT 2 REFERENCES CALLED OUT IN PARAGRAPH B.1.2 OF THIS TRA DESKBOOK

(b) OMB Circular A-11, *Preparing, Submitting, and Executing the Budget,* June 27, 2002.

(e) Chairman of the Joint Chiefs of Staff Instruction 3170.01 Series, *Requirements Generation System,* current edition.

(g) Section 2399 of title 10, United States Code, *Operational Test and Evaluation of Defense Acquisition Programs*.

(j) Section 2377 of title 10, United States Code, *Preference for Acquisition of Commercial Items*.

(k) Section 2435 of title 10, United States Code, *Baseline Description*.

(l) Section 306 of title 5, United States Code, *Strategic Plans* (part of the Government Performance and Results Act).

(m) Section 2432 of title 10, United States Code, *Selected Acquisition Reports*.

(n) Section 2433 of title 10, United States Code, *Unit Cost Reports*.

(o) Section 2366 of title 10, United States Code, *Major Systems and Munitions Programs: Survivability and Lethality Testing Required Before Full-scale Production*.

(p) Section 2440 of title 10, United States Code, *Technology and Industrial Base Plans*.

(q) Section 2400 of title 10, United States Code, *Low-rate Initial Production of New Systems*.

(r) Section 2434 of title 10, United States Code, *Independent Cost Estimates; Operational Manpower Requirements*.

(s) Section 2350a of title 10, United States Code, *Cooperative Research and Development Programs: Allied Countrie*s.

(t) Section 1401 et seq. of title 40, United States Code, *Clinger-Cohen Act of 1996*.

(u) House Report 103-357, November 10, 1993.

(v) DoD Appropriations Act, 2001 (Pub. L. 106-259), Section 8102 (or successor provision).

(w) Section 811 of the National Defense Authorization Act for Fiscal Year 2001.

(x) Section 305 of title 47, United States Code, *Government-Owned Stations*.

(y) Section 104 of the National Telecommunications and Information Organization Act, *Spectrum Management Activities*.

(z) Sections 901, 902, 903, and 904 of title 47, United States Code.

(aa) DoD Directive 4650.1, *Management and Use of the Radio Frequency Spectrum,* June 24, 1987.

(ab) Section 2464 of title 10, United States Code, *Core Logistics Functions*.

(ac) Section 2460 of title 10, United States Code, *Definition of Depot-Level Maintenance and Repair*.

(ad) Section 2466 of title 10, United States Code, *Limitations on the Performance of Depot-Level Maintenance of Material*.

(ae) Section 2469 of title 10, United States Code, *Contracts to Perform Workloads Previously Performed by Depot-Level Activities of the Department of Defense: Requirement of Competition*.

(af) DoD Directive 5105.21, *Defense Intelligence Agency (DIA),* February 18, 1997.

(ag) DoD Instruction 4630.8, *Procedures for Interoperability and Supportability of Information Technology (IT) and National Security Systems (NSS),* May 2, 2002.

(ah) DoD Directive 4630.5, *Interoperability and Supportability of Information Technology (IT) and National Security Systems (NSS),* January 11, 2002.

(ai) DoD Directive 5200.39, *Security, Intelligence, and Counterintelligence Support to Acquisition Program Protection,* September 10, 1997.

B.1.3 Extracts From the *Interim Defense Acquisition Guidebook*

- **Paragraph C7.5.1**

  Technology maturity shall measure the degree to which proposed critical technologies meet program objectives. Technology maturity is a principal element of program risk. A technology readiness assessment shall examine program concepts, technology requirements, and demonstrated technology capabilities to determine technological maturity.

- **Paragraph C7.5.2**

  The PM shall identify critical technologies via the WBS (see paragraph C5.3.1.). Technology readiness assessments for critical technologies shall occur sufficiently prior to milestone decision points B and C to provide useful technology maturity information to the acquisition review process.

- **Paragraph C7.5.3**

  The DoD Component Science and Technology (S&T) Executive shall direct the technology readiness assessment and, for ACAT ID and ACAT IAM programs, submit the findings to the CAE, who shall submit his or her report to the DUSD(S&T) with a recommended technology readiness level (TRL) (or some equivalent assessment) for each critical technology. When the Component S&T Executive submits his or her findings to the CAE, he or she shall provide the DUSD(S&T) an information copy of those findings. In cooperation with the Component S&T Executive and the program office, the DUSD(S&T) shall evaluate the technology readiness assessment and, if he/she concurs, forward findings to the OIPT leader and DAB. If the DUSD(S&T) does not concur with the technology readiness assessment findings, an independent technology readiness assessment, under the direction of the DUSD(S&T), shall be required.

- **Paragraph C7.5.4**

  TRL descriptions appear at Appendix 6. TRLs enable consistent, uniform, discussions of technical maturity, across different types of technologies. Decision authorities shall consider the recommended TRLs (or some equivalent assessment methodology (e.g., Willoughby templates) when assessing program risk. TRLs are a measure of technical maturity. They do not discuss the probability of occurrence (i.e., the likelihood of attaining required maturity) or the impact of not achieving technology maturity.

- **Paragraph C7.6.4.4**

  For ACAT ID decision points, the OIPT leader shall provide the DAB chair, principals, and advisors an integrated assessment using information gathered through the IPT process. The leader's assessment shall focus on core acquisition management issues and shall consider independent assessments, including technology readiness assessments, which the OIPT members normally prepare. These assessments typically occur in context of the OIPT review and shall be reflected in the OIPT leader's report. There shall be no surprises at this point—all team members shall work issues in real time and shall be knowledgeable of their OIPT leader's assessment. OIPT and other staff members shall not require the PM to provide pre-briefs independent of the OIPT process.

- **Paragraph C7.6.7**

  Independent Assessments. Assessments, independent of the developer and the user, ensure an impartial evaluation of program status. Consistent with statutory requirements and good management practice, the Department of Defense shall require independent assessments of program status (e.g., the independent *cost estimate or technology readiness assessment). Senior acquisition officials shall consider these assessments when making acquisition decisions. Staff offices that provide independent assessments shall support the orderly and timely progression of programs through the acquisition process. IPTs shall have access to independent assessments to enable full and open discussion of issues.*

B.2 EXTRACTS FROM THE ACQUISITION POLICY MEMORANDUM *INTERIM GUIDEBOOK* THAT SUGGEST TRA RESPONSIBILITIES

B.2.1 Program Manager (PM)

- ***Interim Guidebook*** **(C7.5.2)**

  The PM shall identify critical technologies via the WBS (see paragraph C5.3.1.). Technology readiness assessments for critical technologies shall occur sufficiently prior to milestone decision points B and C to provide useful technology maturity information to the acquisition review process.

- ***Interim Guidebook*** **(C7.3.1.4)**

  The PM shall brief the acquisition program to the DAB and specifically emphasize technology maturity, risk management, affordability, critical program information, technology protection, and rapid delivery to the user. The PM shall address any interoperability and supportability requirements linked to other systems, and indicate whether those requirements will be satisfied by the acquisition strategy under review. If the program is part of a system-of-systems architecture, the PM shall brief the DAB in that context. If the architecture includes less than ACAT I programs that are key to achieving the expected operational capability, the PM shall also discuss the status of and dependence on those programs.

- ***Interim Guidebook*** **(C7.3.2.3)**

  Principal participants at DoD CIO reviews shall include (as appropriate to the issue being examined) the following department officials: the Deputy DoD CIO; IT OIPT Leader; ACAT ID OIPT Leaders; Cognizant PEO(s) and PM(s); Cognizant OSD PSA, CAEs and CIOs of the Army, Navy, and Air Force. Participants shall also include (as appropriate to the issue being examined) executive-level representatives from the following organizations: Office of USD(AT&L); Office of the Under Secretary of Defense (Comptroller); Office of the Joint Chiefs of Staff; Office of DOT&E; Office of the Director, PA&E; and Defense Information Systems Agency.

- ***Interim Guidebook* (C7.6.4.1)**

  All ACAT ID and IAM programs shall have an OIPT to provide assistance, oversight, and review as the program proceeds through its acquisition life cycle. An appropriate official within OSD, typically the Director of Strategic and Tactical Systems or the Principal Director, Command, Control, Communications, Intelligence, Surveillance, and Reconnaissance & Space, shall lead the OIPT for ACAT ID programs. The Deputy DoD CIO or designee shall lead the OIPT for ACAT IAM programs. The OIPT for ACAT IAM programs is called the IT OIPT. OIPTs shall comprise the PM, PEO, Component Staff, Joint Staff, and OSD staff involved in oversight and review of the particular ACAT ID or IAM program.

- ***Interim Guidebook* (C7.6.5.1)**

  The PM, or designee, shall form and lead an IIPT to support the development of strategies for acquisition and contracts, cost estimates, evaluation of alternatives, logistics management, training, cost-performance trade-offs, etc. The PM, assisted by the IIPT, shall develop and propose to the OIPT, a WIPT structure. The IIPT shall coordinate the activities of the WIPTs and review issues they do not address. WIPTs shall meet as required to help the PM plan program structure and documentation and resolve issues. …

- ***Interim Guidebook* (C7.7.1)**

  It shall be Department policy to keep reporting requirements to a minimum. Nevertheless, complete and current program information is essential to the acquisition process. Consistent with the tables of required regulatory and statutory information appearing in DoD Instruction 5000.2 (reference (a)), decision authorities shall require PMs and other participants in the Defense acquisition process to present only the minimum information necessary to understand program status and make informed decisions. The MDA shall "tailor-in" program information case-by-case, as necessary. IPTs shall facilitate the management and exchange of program information.

- ***Interim Guidebook* (C7.15.1.1)**

  Program plans describe the detailed activities of the acquisition program. In coordination with the PEO, the PM shall determine the type and number of program plans needed to manage program execution.

B.2.2 Deputy Under Secretary of Defense for Science and Technology DUSD(S&T)

- ***Interim Guidebook*** **(C7.5.3)**

  The DoD Component Science and Technology (S&T) Executive shall direct the technology readiness assessment and, for ACAT ID and ACAT IAM programs, submit the findings to the CAE who shall submit his or her report to the DUSD(S&T) with a recommended technology readiness level (TRL) (or some equivalent assessment) for each critical technology. When the Component S&T Executive submits his or her findings to the CAE, he or she shall provide the DUSD(S&T) an information copy of those findings. In cooperation with the Component S&T Executive and the program office, the DUSD(S&T) shall evaluate the technology readiness assessment and, if he/she concurs, forward findings to the OIPT leader and DAB. If the DUSD(S&T) does not concur with the technology readiness assessment findings, an independent technology readiness assessment, under the direction of the DUSD(S&T), shall be required.

- ***Interim Guidebook*** **(C7.6.7)**

  Independent Assessments. Assessments, independent of the developer and the user, ensure an impartial evaluation of program status. Consistent with statutory requirements and good management practice, the Department of Defense shall require independent assessments of program status (e.g., the independent cost estimate or technology readiness assessment). Senior acquisition officials shall consider these assessments when making acquisition decisions. Staff offices that provide independent assessments shall support the orderly and timely progression of programs through the acquisition process. IPTs shall have access to independent assessments to enable full and open discussion of issues.

B.2.3 Component Acquisition Executive (CAE)

- ***Interim Guidebook*** **(C7.5.3)**

  The DoD Component Science and Technology (S&T) Executive shall direct the technology readiness assessment and, for ACAT ID and ACAT IAM programs, submit the findings to the CAE who shall submit his or her report to the DUSD(S&T) with a recommended technology readiness level (TRL) (or some equivalent assessment) for each critical technology. When the Component S&T Executive submits his or her findings to the CAE, he or she shall provide the DUSD(S&T) an information copy of those findings. In cooperation with the Component S&T Executive and the program office, the DUSD(S&T) shall evaluate the technology readiness assessment and, if he/she *concurs, forward findings to the OIPT leader and DAB. If the DUSD(S&T) does not concur with the technology readiness assessment findings, an independent technology readiness assessment, under the direction of the DUSD(S&T), shall be required.*

B.2.4 Component Science and Technology (S&T) Executive

- ***Interim Guidebook*** **(C7.5.3)**

  The DoD Component Science and Technology (S&T) Executive shall direct the technology readiness assessment and, for ACAT ID and ACAT IAM programs, submit the findings to the CAE who shall submit his or her report to the DUSD(S&T) with a recommended technology readiness level (TRL) (or some equivalent assessment) for each critical technology. When the Component S&T Executive submits his or her findings to the CAE, he or she shall provide the DUSD(S&T) an information copy of those findings. In cooperation with the Component S&T Executive and the program office, the DUSD(S&T) shall evaluate the technology readiness assessment and, if he/she concurs, forward findings to the OIPT leader and DAB. If the DUSD(S&T) does not concur with the technology readiness assessment findings, an independent technology readiness assessment, under the direction of the DUSD(S&T), shall be required.

B.2.5 Defense Acquisition Board (DAB) [Chaired by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L))]

- ***Interim Guidebook*** **(C7.3.1.1)**

  The DAB shall advise the Under Secretary of Defense (Acquisition, Technology, and Logistics) on critical acquisition decisions. The Under Secretary of Defense (Acquisition, Technology, and Logistics) shall chair the DAB, and the Vice Chairman of the Joint Chiefs of Staff shall serve as vice-chair. DAB membership shall comprise the following executives: Under Secretary of Defense (Comptroller); Under Secretary of Defense (Policy); Under Secretary of Defense (Personnel & Readiness); Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)/Department of Defense Chief Information Officer; Director, Operational Test and Evaluation; and the Secretaries of the Army, Navy, and the Air Force. United States Joint Forces Command shall be available to comment on interoperability and integration issues that the JROC forwards to the DAB. The DAE may ask other department officials to participate in reviews, as required.

B.2.6 Defense Acquisition Executive (DAE)

- ***Interim Guidebook*** **(C7.3.1.3)**

  The Defense Acquisition Executive shall conduct DAB reviews at major program milestones and at the Full-Rate Production Decision Review (if not delegated to the CAE), and at other times, as necessary. An ADM shall document the decision(s) resulting from the review.

B.2.7 DoD Chief Information Officer (CIO)

- ***Interim Guidebook*** **(C7.3.2.1)**

  DoD CIO Reviews shall provide the forum for ACAT IAM milestones, for deciding critical ACAT IAM issues when they cannot be resolved at the OIPT level, and for enabling the execution of the DoD CIO's acquisition-related responsibilities for IT, including NSS, under the Clinger-Cohen Act and Title 10 USC (references (bn) and (dd)). Wherever possible, these reviews shall take place in the context of the existing IPT and acquisition milestone review process. Where appropriate, an ADM shall typically document the decision(s) resulting from the review.

B.2.8 Overarching Integrated Product Team (OIPT)

- ***Interim Guidebook*** **(C7.6.4.1)**

  All ACAT ID and IAM programs shall have an OIPT to provide assistance, oversight, and review as the program proceeds through its acquisition life cycle. An appropriate official within OSD, typically the Director of Strategic and Tactical Systems or the Principal Director, Command, Control, Communications, Intelligence, Surveillance, and Reconnaissance & Space, shall lead the OIPT for ACAT ID programs. The Deputy DoD CIO or designee shall lead the OIPT for ACAT IAM programs. The OIPT for ACAT IAM programs is called the IT OIPT. OIPTs shall comprise the PM, PEO, Component Staff, Joint Staff, and OSD staff involved in oversight and review of the particular ACAT ID or IAM program.

- ***Interim Guidebook*** **(C7.6.4.2)**

  The OIPT shall form upon departmental intention to start an acquisition program. The OIPT shall charter the IIPT and WIPTs. The OIPT shall consider the recommendations of the IIPT regarding the appropriate milestone for program initiation and the minimum information needed for the program initiation milestone review. OIPTs shall meet, thereafter, as necessary over the life of the program. The OIPT leader shall act to resolve issues when requested by any member of the OIPT, or when so directed by the MDA. The goal is to *resolve as many issues and concerns at the lowest level possible, and to expeditiously escalate issues that need resolution at a higher level. The OIPT shall bring only the highest-level issues to the MDA for decision.*

- ***Interim Guidebook*** **(C7.6.4.3)**

  The OIPT shall normally convene two weeks before a planned decision point. It shall assess the information and recommendations that the MDA will receive, in the same context, and to the same ACAT level. It shall also assess family-of-system or system-of-system capabilities within mission areas in support of mission area operational architectures developed by the Joint Staff. If the program includes a pilot project, such as TOC Reduction, the PM shall report the status of the project to the OIPT. The OIPT shall then assess progress against stated goals. The PM's briefing to the OIPT shall specifically address interoperability and supportability (including spectrum supportability) with other systems, anti-tamper provisions, and indicate whether those requirements will be satisfied by the acquisition strategy under review. If the program is part of a family-of-systems architecture, the PM shall brief the OIPT in that context. If the architecture includes less than ACAT I programs that are key to achieving the expected operational capability, the PM shall also discuss the status of and dependence on those programs. The OIPT leader shall recommend to the MDA whether the anticipated review should go forward as planned.

- ***Interim Guidebook*** **(C7.6.4.4)**

  For ACAT ID decision points, the OIPT leader shall provide the DAB chair, principals, and advisors an integrated assessment using information gathered through the IPT process. The leader's assessment shall focus on core acquisition management issues and shall consider independent assessments, including technology readiness assessments, which the OIPT members normally prepare. These assessments typically occur in context of the OIPT review, and shall be reflected in the OIPT leader's report. There shall be no surprises at this point—all team members shall work issues in real time and shall be knowledgeable of their OIPT leader's assessment. OIPT and other staff members shall not require the PM to provide pre-briefs independent of the OIPT process.

B.2.9 Integrated Product Teams (IPTs)

- ***Interim Guidebook*** **(C7.6.2)**

  IPTs are an integral part of the Defense acquisition oversight and review process. For ACAT ID and IAM programs, there are generally two levels of IPT: the OIPT and WIPT(s). Each program shall have an OIPT and at least one WIPT. WIPTs shall focus on a particular topic such as cost/performance, test, *or contracting. An Integrating IPT (IIPT) (which is a WIPT) shall coordinate WIPT efforts and cover all topics not otherwise assigned to another IPT. IPT participation is the primary way for any organization to participate in the acquisition program.*

INTERIM GUIDEBOOK REFERENCES CALLED OUT IN PARAGRAPHS B.2.1 AND B.2.7 OF THIS TRA DESKBOOK

(a) DoD Instruction 5000.2, "Operation of the Defense Acquisition System," April 5, 2002.

(bn) Section 1401 et seq. of title 40, United States Code, "Clinger-Cohen Act of 1996."

(dd) Title 10, United States Code, "Armed Forces."

ACRONYMS FOR APPENDIX B

ACAT	Acquisition Category
ADM	Acquisition Decision Memorandum
AIS	Automated Information System
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
AT&L	Acquisition, Technology, and Logistics
BES	Budget Estimate Submission
C3I	command, control, communications, and intelligence
C4I	command, control, communications, computers, and intelligence
C4ISP	Command, Control, Communications, Computers, and Intelligence Support Plan
CAE	Component Acquisition Executive
CAIG	Cost Analysis Improvement Group
CCA	Component Cost Analysis
CDD	Capability Development Document
CIO	Chief Information Officer
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CPD	Capability Production Document
CPI	Critical Program Information
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DAES	Defense Acquisition Executive Summary
DD	Department of Defense (as in DD Form 1494)
DIA	Defense Intelligence Agency
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOT&E	Director of Operational Test and Evaluation
DOTMLPF	doctrine, organization, training, materiel, leadership, personnel, and facilities
DR	Decision Review
DUSD(S&T)	Deputy Under Secretary of Defense for Science and Technology

EW	Electronic Warfare
FOT&E	Follow-on Operational Test and Evaluation
FRP	full-rate production
HR	House of Representatives
ICD	Initial Capabilities Document
ICE	independent cost estimate
IIPT	Integrating IPT
IOT&E	Initial Operational Test and Evaluation
IPT	Integrated Product Team
IT OIPT	Information Technology Overarching Integrated Product Team
IT	Information Technology
JROC	Joint Requirements Oversight Committee
KPP	key performance parameter
LFT&E	Live Fire Test and Evaluation
LRIP	low rate initial production
MAIS	Major Automated Information System
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MS	Milestone
NSS	National Security Systems
OIPT	Overarching Integrated Product Team
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
OUSD(P&R)	Office of the Under Secretary of Defense for Personnel and Readiness
PA&E	Program Analysis and Evaluation
PEO	Program Executive Officer
PM	Program Manager
POM	Program Objective Memorandum
PPP	Program Protection Plan
PSA	Principal Staff Assistant
RCS	Report Control Symbol
S&T	Science and Technology
SAR	Selected Acquisition Report

T&E	test and evaluation
TEMP	Test and Evaluation Master Plan
TOC	total ownership cost
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
U.S.C.	United States Code
UCR	Unit Cost Report
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
WBS	Work Breakdown Structure
WIPT	Working Integrated Product Team

APPENDIX C
SEC. 804 OF THE NATIONAL DEFENSE AUTHORIZATION ACT (NDAA) FOR FISCAL YEAR 2002, CONFERENCE REPORT

Appendix C contains SEC. 804 of the NDAA for Fiscal Year 2002, Conference Report, which requires the Secretary of Defense to submit reports on the implementation of the DoD technology readiness policy. The Director of Defense Research and Engineering (DDR&E) is responsible for preparing these reports.

107TH CONGRESS
1st Session

HOUSE OF REPRESENTATIVES

REPORT
107–333

NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2002

CONFERENCE REPORT

TO ACCOMPANY

S. 1438

DECEMBER 12, 2001.—Ordered to be printed

SEC. 804. REPORTS ON MATURITY OF TECHNOLOGY AT INITIATION OF MAJOR DEFENSE ACQUISITION PROGRAMS.

(a) REPORTS REQUIRED.—Not later than March 1 of each of years 2003 through 2006, the Secretary of Defense shall submit to the Committees on Armed Services of the Senate and the House of Representatives a report on the implementation of the requirement in paragraph 4.7.3.2.2.2 of Department of Defense Instruction 5000.2, as in effect on the date of enactment of this Act, that technology must have been demonstrated in a relevant environment (or, preferably, in an operational environment) to be considered mature enough to use for product development in systems integration.

(b) CONTENTS OF REPORTS.—Each report required by subsection (a) shall—

(1) identify each case in which a major defense acquisition program entered system development and demonstration during the preceding calendar year and into which key technology has been incorporated that does not meet the technological maturity requirement described in subsection (a), and provide a justification for why such key technology was incorporated; and

(2) identify any determination of technological maturity with which the Deputy Under Secretary of Defense for Science and Technology did not concur and explain how the issue has been or will be resolved.

(c) MAJOR DEFENSE ACQUISITION PROGRAM DEFINED.—In this section, the term "major defense acquisition program" has the meaning given that term in section 139(a)(2) of title 10, United States Code.

APPENDIX D
TECHNOLOGY READINESS LEVEL (TRL) EXAMPLES

Table III-1 of the TRA Deskbook contains the definitions of the various TRLs and notes some of the information that supports assignment of a technology to specific levels of readiness. To aid in making the definitions more concrete, this appendix contains examples of readiness levels for technologies as they evolved to full maturity.

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1 Compliments of the Army, in which the evolution of a technology is depicted graphically.

2 Compliments of the Navy, in which the evolution of a materials technology is presented, including a full description at each TRL.

RING LASER GYRO

Technology Readiness Example

Level	Technology Readiness	Example – HG1700 Inertial Measurement Unit (IMU) Guided Multiple Launch Rocket System (GMLRS)
1	Basic Principles observed and reported	**Basic research** – Invention of Gas Laser
2	Technology concept and/or application formulated	**Basic research** – Invention of Ring Laser. Theoretical description of Ring Laser Gyro (RLG)
3	Analytical and experimental critical function and/or characteristic proof of concept	**Applied research** – Demonstration of Ring Laser as a rate sensor
4	Component and/or breadboard validation in laboratory environment	**Applied research** – Demonstration of RLG-based IMU operation under temperature, shock, vibration, and g-loading
5	Component and/or breadboard validation in relevant environment	**Advanced Technology Demonstration** (ATD) – Demonstration of HG1700-based guidance set components [IMU, Global Positioning system (GPS) receiver, control system, flight computer] in a high-fidelity hardware-in-the-loop facility
6	System/subsystem model or prototype demonstrated in a relevant environment	**ATD** – Demonstration of actual flight-ready HG1700-based guidance set in a high-fidelity hardware-in-the-loop facility and under expected levels of shock, vibration, altitude, and temperature
7	System prototype demonstrated in an operational environment	**System Design and Development (SDD)** – Demonstration of actual GMLRS missile in a flight test sequence from an operational launcher. Successful operation in multiple flight demonstrations
8	Actual system completed and "flight qualified" through test and demonstration	**Low Rate Initial Production (LRIP)** – Developmental Test and Evaluation (DT&E) of GMLRS in its final form under mission conditions
9	Actual system "flight proven" through successful mission operations	**Production** – Operational Test and Evaluation (OT&E) of GMLRS by the soldier, airman, or seaman

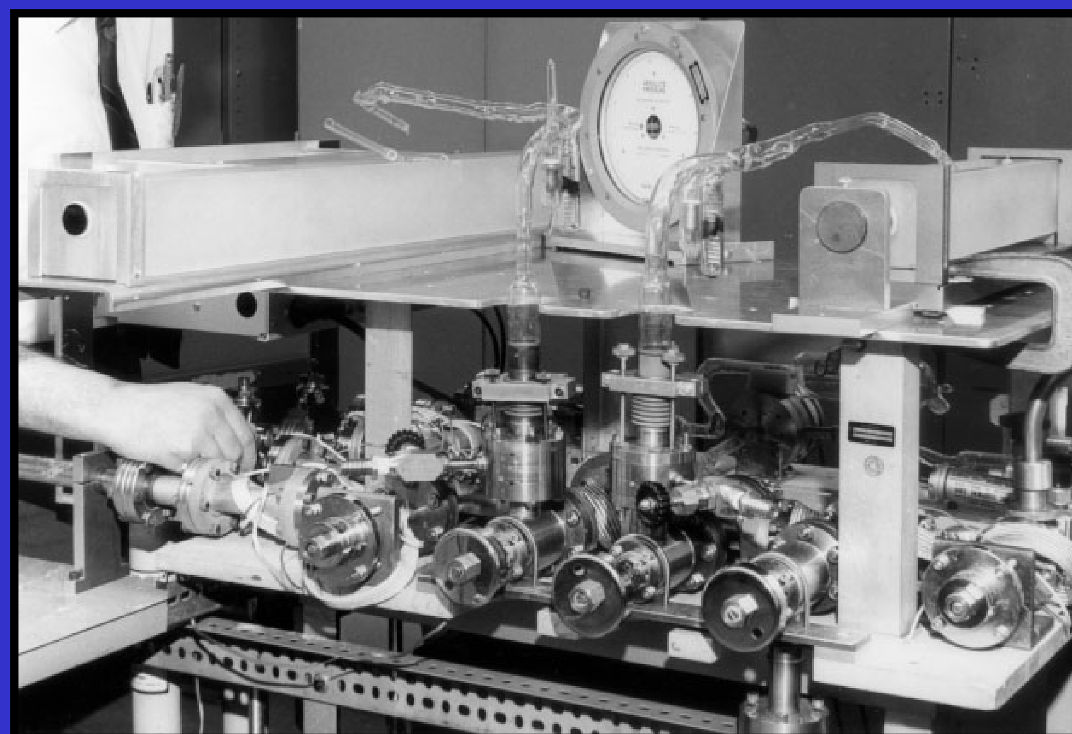
Technology Readiness Example

Level	Technology Readiness	Example – HG1700 IMU GMLRS
1	Basic Principles observed and reported	**Basic research** – Invention of Gas Laser
2	Technology concept and/or application formulated	**Basic research** – Invention of Ring Laser. Theoretical description of RLG

Laser

Research

Facility

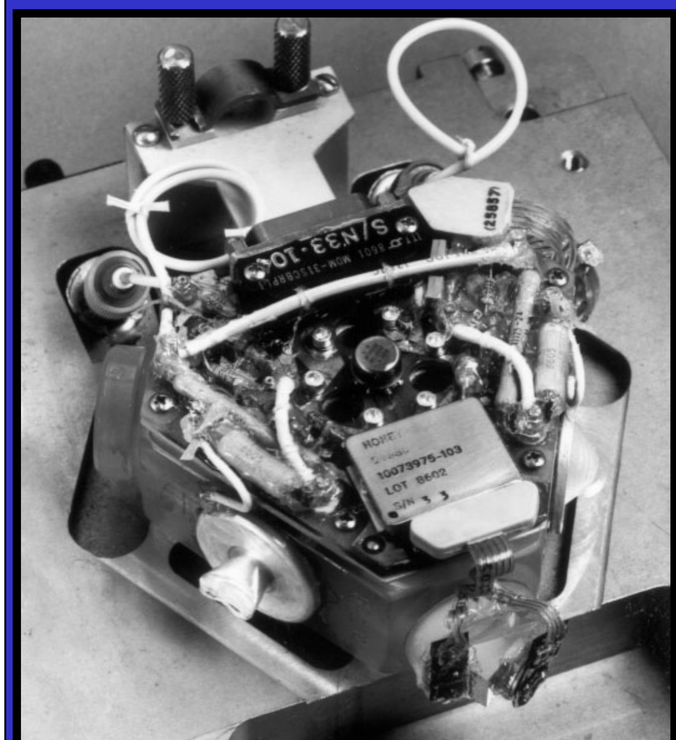


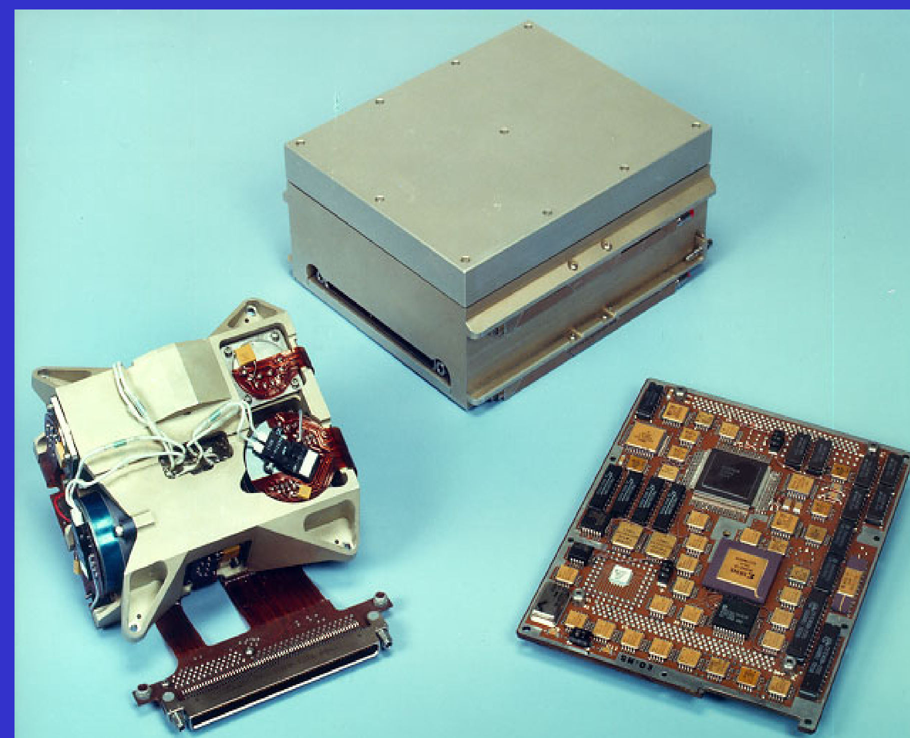
circa 1960

Technology Readiness Example

Level	Technology Readiness	Example – HG1700 IMU GMLRS
3	Analytical and experimental critical function and/or characteristic proof of concept	**Applied research** – Demonstration of Ring Laser as a rate sensor

Ring Laser Gyro circa 1975





HG1108 Inertial Measurement Unit circa 1990

Technology Readiness Example

Level	Technology Readiness	Example – HG1700 IMU GMLRS
5	Component and/or breadboard validation in relevant environment	**ATD** – Demonstration of HG1700-based guidance set components (IMU, GPS receiver, control system, flight computer) in a high-fidelity hardware-in-the-loop facility

Technology Readiness Example

Level	Technology Readiness	Example – HG1700 IMU GMLRS
6	System/subsystem model or prototype demonstrated in a relevant environment	**ATD** – Demonstration of actual flight-ready HG1700-based guidance set in a high-fidelity hardware-in-the-loop facility and under expected levels of shock, vibration, altitude, and temperature

Technology Readiness Example

Level	Technology Readiness	Example – HG1700 IMU GMLRS
7	System prototype demonstrated in an operational environment	**SDD** – Demonstration of actual GMLRS missile in a flight test sequence from an operational launcher. Successful operation in multiple flight demonstrations

Advanced Technology Demonstration

GPS-aided IMU Flight
(2m miss at 49 km range)

Technology Readiness Example

Level	Technology Readiness	Example – HG1700 IMU GMLRS
8	Actual system completed and "flight qualified" through test and demonstration	**LRIP** – DT&E of GMLRS in its final form under mission conditions
9	Actual system "flight proven" through successful mission operations	**Production** – OT&E of GMLRS by the soldier, airman, or seaman

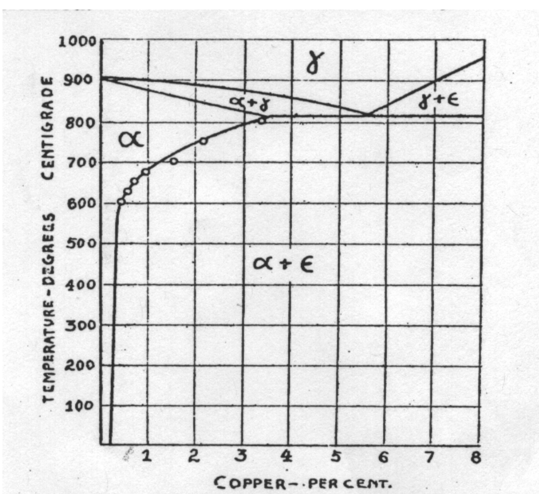
TECHNOLOGY STEEL READINESS LEVELS
EXAMPLE: HSLA-100 STEEL FOR AIRCRAFT CARRIER STRUCTURE
MARCH 2002

Technology Readiness Level 1: Basic Principles Observed and Reported

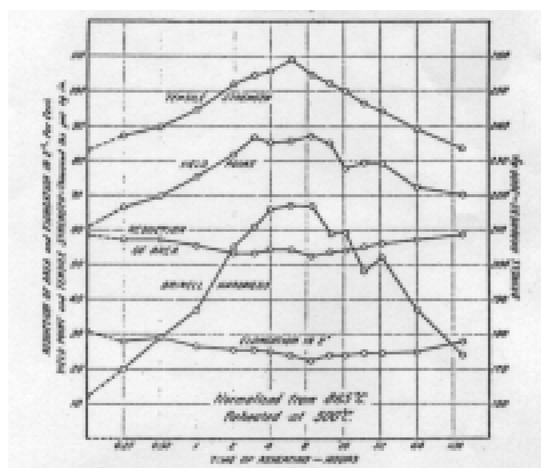
The lowest Technology Readiness Level (TRL), where scientific research begins to be translated into technology's basic properties.

With the mass industrialization of structural steel welding for shipbuilding in World War II, the quest for high-strength steels with good weldability was a motivation for metallurgical research that continued through the post-war era. Carbon strengthening and alloying that resulted in high strength was counter to weldability. The fundamental metallurgical tools for steel alloy design (e.g., phase transformation, phase diagrams, relationship of microstructure to properties, precipitation strengthening, and so forth) were developing at a dramatic rate along with the U.S. steel industry.

In the 1930s, the unique property of precipitation hardening induced by alloying of copper in steel was established. The phase diagrams for the Fe-Cu system were formulated, the solubility limits of Cu in low carbon steel were explored, and laboratory studies of copper steels were conducted. However, the benefit of Cu-strengthening as a means toward optimum strength, toughness, and weldability was not recognized.



Fe-Cu Phase Diagram



Precipitation Hardening in Heat Treatment of an 0.27% C, 1% Cu Steel

Key References:

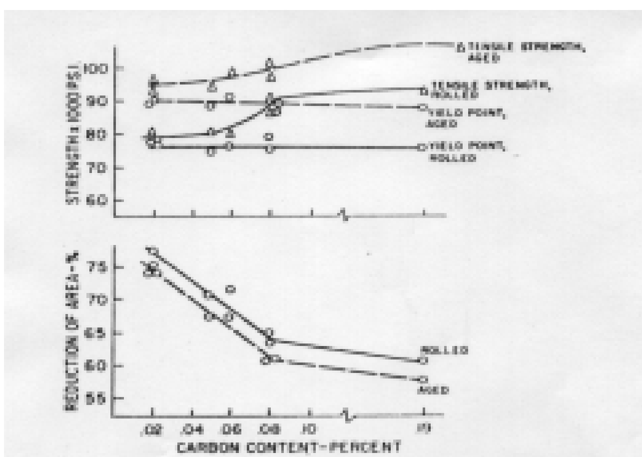
Smith, C.S. and E.W. Palmer, "The Precipitation-hardening of Copper Steels," *Trans. AIME*, Vol. 105 (1933).

Technology Readiness Level 2: Invention Begins

Once basic principles are observed, practical applications can be invented. However, the application is speculative, and no proof or detailed analysis exists to support the assumption.

In the mid-1960s, the laboratories of the International Nickel Company (INCO) initiated the development of a class of low-carbon, age-hardening Ni-Cu-Cb steels called “NiCuAge” steels. The work focused on the very-low-carbon, with changes in Ni, Cu, and Cb content and processing (hot working schedules and heat treatment) to establish microstructure-mechanical property relationships. The combinations of strength, ductility, and processing characteristics exhibited by the Ni-Cu-Cb steels suggested a variety of applications in transportation, automotive, and oil field construction. Because of the low carbon content, the steel offered excellent formability and weldability in the fully strengthened condition.

The key concepts discovered at this stage were the importance of Ni and Cb additions to the copper steels. The Ni addition and the ratio of Ni-to-Cu were established as a means to prevent cracking during hot working. Researchers discovered that small additions of Cb significantly increased strength, provided grain refinement, and did not degrade any characteristics of the steel. At this stage, small laboratory melts (30 lb) were used for the alloy composition optimization.



Tensile Ductility of Ni-Cu Steel as Influenced by Carbon Content

Key References:

Hurley, J.L. and C.H. Shelton, “Age-Hardenable Nickel-Copper Steels,” *Metals Engineering Quarterly,* ASM, May 1966.

Technology Readiness Level 3: Active Research and Development (R&D) Is Initiated

This includes analytical and laboratory studies to validate physically the analytical predictions of separate elements of the technology.

INCO continued the development of improved "NiCuAge" steel for improved weldability and low-temperature toughness in heavy section plates and forgings and, in 1972, marketed the steel designated IN-787 for offshore platforms and ship hull plates. The American Society for Testing and Materials (ASTM) Standard Specification A710, Grade A, based on IN-787 steel, was issued in 1975. Armco Steel Corporation produced a plate to ASTM A710, Grade A, under the trade name "NI-COP" steel.

The primary reason for preheat in the welding of High Yield Strength (HY)-80 and HY-100 steels is to mitigate underbead cracking (hydrogen related) in the hard, martensitic heat-affected zone (HAZ). The Navy High-Strength Low-Alloy (HSLA)-80, an optimized version of ASTM A710, Grade A steel, is a ferritic steel. The microstructure of the quenched and aged HSLA-80 plate product is generally an acicular ferrite. Ferritic steels are widely used in civil construction because of their excellent weldability.

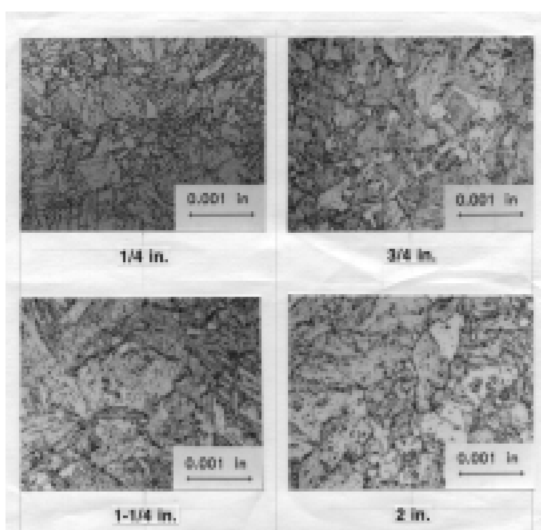
In 1981, the Navy HSLA Steels Exploratory Development Program was initiated at David Taylor Research Center (DTRC), with ASTM A710, Grade A selected as the primary candidate. Because of the positive results emanating from the project, ASTM A710, Grade A, Class 3 steel was authorized as substitute for HY-80 steel on a production trial basis in CVN 71 in selected noncritical, nonwetted areas in 1983. Upon completion of the evaluation of ASTM A710 for Navy requirements, the modifications to ASTM A710 were incorporated in MIL-S-24645(SH), 4 September 1984, for HSLA-80 steel plate, sheet, and coil. The Naval Sea Systems Command (NAVSEA) certified HSLA-80 for surface ship construction and repair in thickness up to 1-1/4 inch, 16 February 1984. The evaluation of HSLA-80 properties, welding, and structural performance demonstrated that the very-low-carbon, copper precipitation-strengthened steel met the requirements of HY-80 steel and was readily weldable with no preheat (32 °F minimum) using the same welding consumables and processes as those used for HY-80 steel fabrication. Since 1985, HSLA-80 steel has been used in CG 47 Class construction in increasing tonnage, in CVN 72 and follow-on ships, and in DDG 51 Class, LHD 1 Class, LSD 41 Class, and FFG 7 Class modifications.

Following the HSLA-80 program, an R&D project commenced in 1985 to establish the feasibility of HSLA-100 steel as a replacement for HY-100 to reduce fabrication costs. A contract to Amax Materials Research Center in 1985 initiated the laboratory alloy development for HSLA-100 steel. The objective for HSLA-100 was to meet the strength and toughness of HY-100 steel but to be weldable without the preheat requirements of HY-100, using the same welding consumables and processes as those used in welding HY-100. The project for the development of HSLA-100 steel in the laboratory alloy design phase used the principles of very-low-carbon, copper-precipitation strengthened steel successful for HSLA-80.

Fracture-process research on HSLA-80 steel indicated that a uniformly small grain size and wider distribution of small carbides would reduce the fracture transition temperature. In fact, HSLA-80 plates of 1-inch gage and less were typically a fine-grained, acicular ferrite microstructure with widely dispersed fine carbides and showed excellent low-temperature toughness. The aim of HSLA-100 alloy design was to produce a homogeneous, fine-grained, low-carbon martensite microstructure that dispersed the secondary transformation products. The alloy development effort to modify HSLA-80 steel microstructurally used laboratory-scale heats (50 to 100 lb) to study the effects of Mn, Ni, Mo, Cu, Cr, Cb, and C in hot rolled, quenched, and aged HSLA-100 plate. Laboratory plates in thicknesses of 1/4, 3/4, 1-1/4, and 2 inches of HSLA-100 exceeded the minimum strength and impact toughness requirements.

Microstructural analysis was conducted to develop composition ranges for heavy gage plate, meeting the strength and toughness requirements, where polygonal ("blocky") ferrite microstructures were not present. A regression analysis was conducted on the results for plates from 45 experimental melts to develop composition ranges for an interim specification for HSLA-100 Steel Plate. The interim specification was then used as the basis for a trial commercial production of HSLA-100 steel by domestic steel plate mills.

The copper content of HSLA-100 steel is higher than that in HSLA-80 [for additional precipitation strengthening (maximum solubility of copper in iron is near 2 percent)], and increased hardenability was achieved by increases in manganese, nickel, and molybdenum. Nickel, the greatest increase over that in HSLA-80, lowers upper shelf impact toughness but also lowers (improves) the impact toughness transition temperature. The microstructure of HSLA-100 steel was identified by optical and scanning electron microscopy as low-carbon martensite or a granular, low-carbon bainite, depending on plate gage—a significantly different metallurgy and microstructure than the ferritic HSLA-80 steel microstructures.



Experimental HSLA-100 Steel Plate Microstructures for a Range of Plate Thickness

Key References:

Certification of HSLA-80 Steel, NAVSEA ltr 05MB/BPS, Ser 5, dated 16 February 1984.

Coldren, A.P. and T.B. Cox, *Development of 100 Ksi Yield Strength HSLA Steel,* DTNSRDC-CR-07-86, July 1986.

Coldren, A.P., T.B. Cox, E.G. Hamburg, C.R. Roper, and A.D. Wilson, *Modification of HSLA-80 Steel to Improve Toughness in Heavy Sections,* DTRC Report SME-CR-04-91, February 1991.

Jesseman, R.J. and G.C. Schmid, "Submerged Arc Welding a Low-Carbon, Copper Strengthened Alloy Steel," *Welding Journal Research Supplement*, Vol. 62, No. 11, November 1983, pp. 321s–330s.

Jesseman, R.J. and G.J. Murphy, "Mechanical Properties and Precipitation Hardening Response in ASTM A710 Grade A and A736 Alloy Steel Plates," *Journal of Heat Treating*, Vol. 3, No. 3, June 1984, pp. 228–236.

Kvidahl, L.G., "An Improved High Yield Strength Steel for Shipbuilding," *Welding Journal*, Vol. 64, No. 7, July 1985, pp. 42–48.

McCaw, R.L. and R.J. Wong, *Welding of HSLA-80 Steel,* DTNSRDC/SME-85/32, June 1985.

Money, K.L., C.H. Shelton, and P.P. Hydrean, "High Strength, Age Hardening Low-Alloy Steel Plate for Offshore Platforms and Hull Plate," *1974 Offshore Technology Conference*, Paper OTC 1952, 1974.

Montemarano, T.W., R.T. Brenna, T.E. Caton, D.A. Davis, R.L. McCaw, L.J. Roberson, T.M. Scoonover, and R.J. Wong, *Results of the Evaluation of ASTM A710, Grade A Steel Under the "Certification of HSLA Steels for Surface Ship Construction Program,"* DTNSRDC TM-28-84-17, January 1984.

Natishan, M.E., *Micromechanisms of Strength and Toughness in a Microalloyed, Precipitation Hardened Steel,* DTRC/SME-89/04, May 1989.

Wilson, A.D., "High Strength, Weldable Precipitation Aged Steels," *Journal of Metals*, March 1987, pp. 36–38.

Technology Readiness Level 4: Basic Technology Components Are Integrated

The basic components of the technology are integrated to establish that the pieces will work together.

For the trial plate-production phase of the HSLA-100 steel project, an initial 150-ton production of HSLA-100 steel was melted and rolled by Phoenix Steel Corporation in 1986 to the interim specification, using conventional electric furnace and ingot casting practice, conducted to achieve a very-low-carbon composition. The minimum strength and toughness requirements of the interim specification were met in the initial production of HSLA-100 steel plate in gages from 1/4 to 2 inches. Optimum properties in HSLA-100 plate resulted from aging temperatures from 1150 to 1275 ºF.

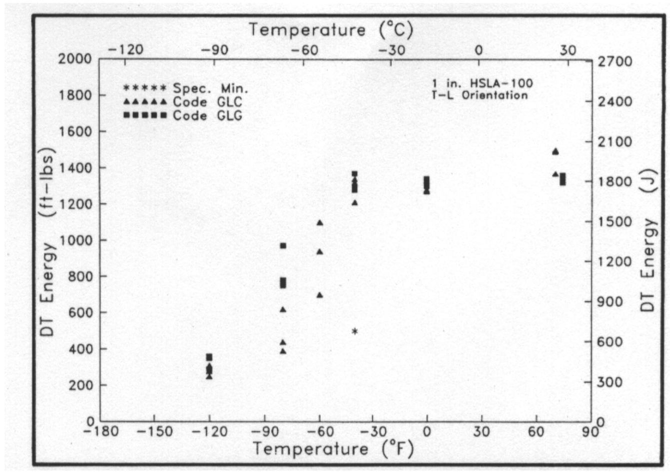
Upon receipt of HSLA-100 plate from the trial productions, an evaluation commenced to evaluate HSLA-100 steel plate and welding using the processes and procedures for HY-100 steel ship and submarine structural applications—but with reduced or no preheat. The evaluation of HSLA-100 steel plate properties and welding demonstrated that HSLA-100 steel met the mechanical property requirements of HY-100 steel and was weldable with reduced preheat requirements, using the same welding consumables as for HY-100 steel fabrication. When compared with HY-100 steel, the tensile and impact toughness properties of the plates met or exceeded the requirements.

The primary reason for preheating when welding the HY-series steels was to mitigate underbead cracking (hydrogen related) in the HAZ. The HSLA-100 precertification evaluation emphasized welding and weldability testing to demonstrate that HSLA-100 was more resistant to hydrogen cracking than HY-100 (to allow a relaxation of preheat requirements). The findings of the HSLA-100 steel welding and weldability evaluations are summarized as follows:

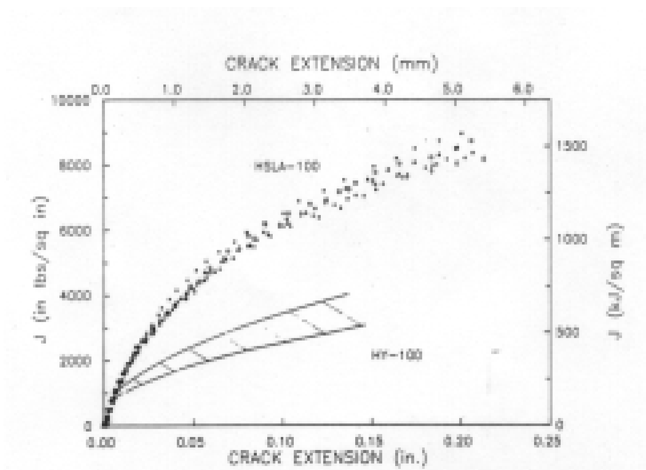
- The strength and toughness of weld metals deposited by the Shielded Metal Arc Welding (SMAW), Submerged Arc Welding (SAW), Pulsed Gas Metal Arc Welding (GMAW-P), and Short Circuiting Gas Metal Arc Welding (GMAW-S) processes, using the welding consumables qualified for HY-100 welding, met the requirements when welded over a broader range of operating conditions (heat inputs ranging from 22 to 65 kJ/in.). No "hard" microstructures were indicated, and the Charpy V-notch toughness of the HAZ in HSLA-100 weldments was equal to or greater than the weld metal toughness.

- It was demonstrated that HSLA-100 fillet weld strengths were equivalent to HY-100 welds using the same process, filler metal, and fillet size.

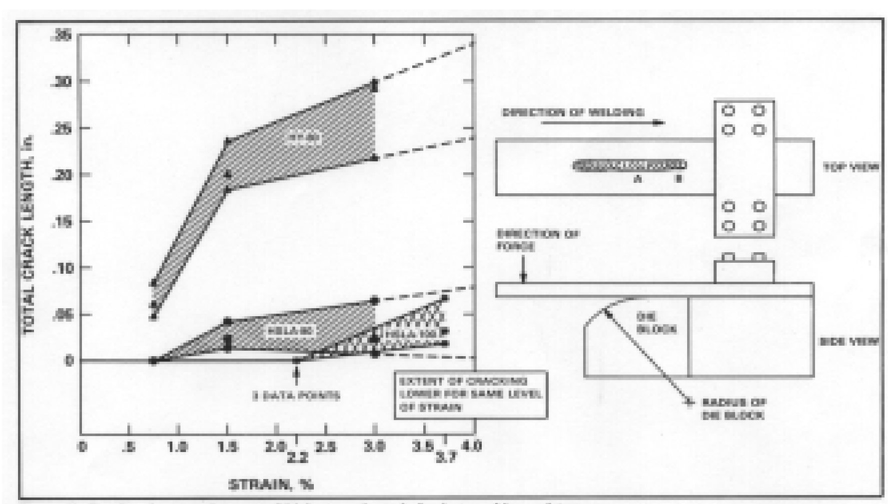
- HSLA-100 plate, weld metal, and weld HAZ did not show any susceptibility to stress corrosion cracking exposed at –1,000 mV at or above stress corrosion cracking threshold stress intensity values determined for HY-100, MIL-100S-1, and MIL-120S-1 weld metals.



Dynamic Tear Test Results for HSLA-100 Steel Plates



Fracture Toughness Test Results of HSLA-100 and HY-100



Varestraint Weldability Tests of High-Strength Steels

Key References:

Coldren, A.P. and T.B. Cox, *Phase II Report and Phase III Commercial Plate Documentation for Development of 100 Ksi Yield Strength HSLA Steel,* DTNSRDC-CR-07-87, June 1987.

Czyryca, E.J., *Trial Production of HSLA-100 Steel Plate,* DTRC Report SME-87/83, February 1988.

Czyryca, E.J. and R.E. Link, *Physical Properties, Elastic Constants, and Metallurgy of HSLA-100 Steel Plate,* DTRC/SME- 88/62, December 1988.

Holsberg, P.W. and R.J. Wong, "Welding of HSLA-100 Steel for Naval Applications," *Weldability of Materials*, ASM International, 1990.

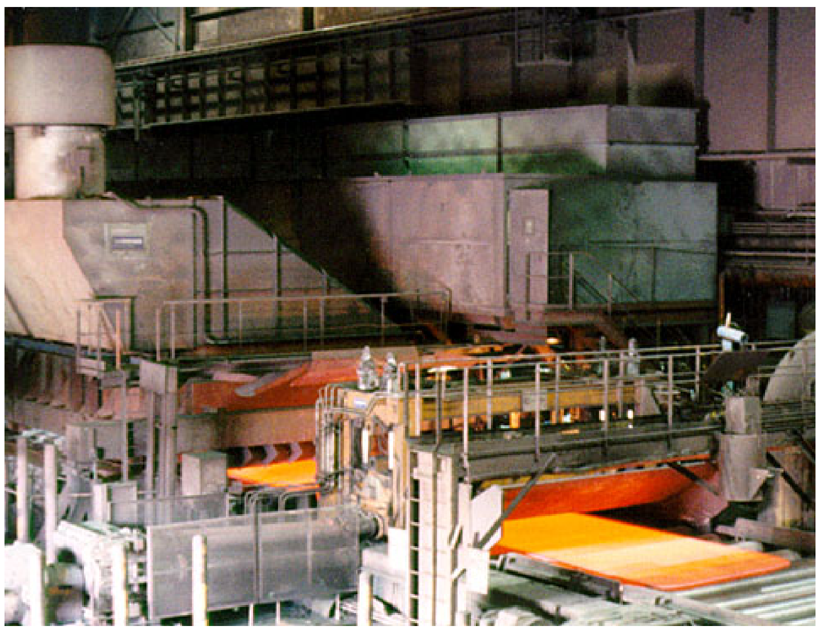
Link, R.E. and E.J. Czyryca, *Mechanical Property Characterization of HSLA-100 Steel Plate,* DTRC/SME-88/38, December 1988.

Wong, R.J., *Weldability and Welding Procedure Development for HSLA-100 Steel Non-Pressure Hull Structures,* DTRC/SME-90/40, September 1990.

Technology Readiness Level 5:
Technology Sufficiently Advanced for Simulation Tests

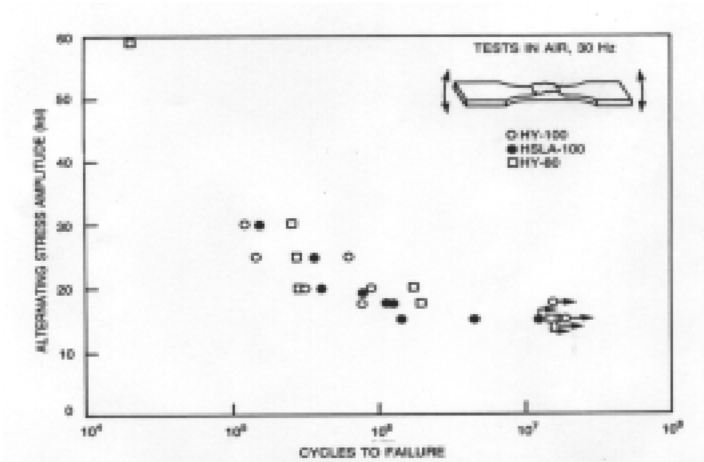
The fidelity of breadboard technology increases significantly enough to justify being ready for testing in a simulated environment.

Lukens Steel Company produced a second melt of HSLA-100 steel, again by electric furnace and ingot casting. Most of the plate produced from the heat was greater than 2 inches thick, primarily for ballistic resistance evaluation. The minimum strength and toughness requirements were met in plate thicknesses from 1/2 to 3-3/4 inches. A double austenitization and quench process was used for HSLA-100 steel plate in gages over 1-1/4 inches to refine the heavy-plate grain structure for optimum toughness. HSLA-100 plate from both productions to the interim specification was the primary material used in the certification program.



The certification evaluation included continued characterization of production HSLA-100 steel plate mechanical, physical, and fracture properties. However, the main focus was the evaluation of weldability and welding process limits for structures of high restraint, studies of fatigue properties, and effects of marine environments on HSLA-100.

The results of low-cycle fatigue crack initiation tests of HSLA-100 steel and weldments and high-cycle fatigue tests in air and seawater showed properties equivalent to HY-100 steel in every case. The steels showed similar fatigue crack growth rate properties. General corrosion, crevice corrosion, galvanic corrosion, and high-velocity seawater parallel flow and cavitation tests of HSLA-100 in seawater showed that the corrosion behavior of HY-100 and HSLA-100 steels was comparable.



Fatigue Test Results for HSLA-100, HY-100, and HY-80 Steel Weldments

Key References:

Aylor, D.M., R.A. Hays, R.E. Rebis, and E.J. Czyryca, *Corrosion and Stress Corrosion of HSLA-100 Steel,* DTRC/SME-90/17, May 1990.

Czyryca, E.J., "Development, Qualification, and Certification of HSLA-80 and HSLA-100 Steels for U. S. Navy Ship Construction: The Metallurgy, Welding, and Qualification of Microalloyed (HSLA) Steel Weldments," *Proceedings of the International Conference,* Houston, Texas, November 6–8, 1990, American Welding Society, Miami, Florida, 1991.

Czyryca, E.J. and R.E. Link, *Fracture Toughness of HSLA-100, HSLA-80, and ASTM A710 Steel Plate,* DTRC/SME-88/64, January 1990.

Czyryca, E.J., *HSLA-100 Steel Plate Production (2nd Production Heat),* DTRC/SME-89/19, July 1989.

Czyryca, E.J., R.E. Link, and R.J. Wong, *Evaluation of HSLA-100 Steel for Surface Combatant Structural Certification,* DTRC/SME-89/15, August 1989.

Czyryca, E.J., R.E. Link, R.J. Wong, D.M. Aylor, T.W. Montemarano, and J.P. Gudas, "Development and Certification of HSLA-100 Steel for Naval Ship Construction," *Naval Engineers Journal*, May 1990, pp. 63–82.

Werchniak, W., E.J. Czyryca, and D.M. Montiel, *Fatigue Properties of HSLA-100 Steel and Weldments,* DTRC/SME-89/113, September 1990.

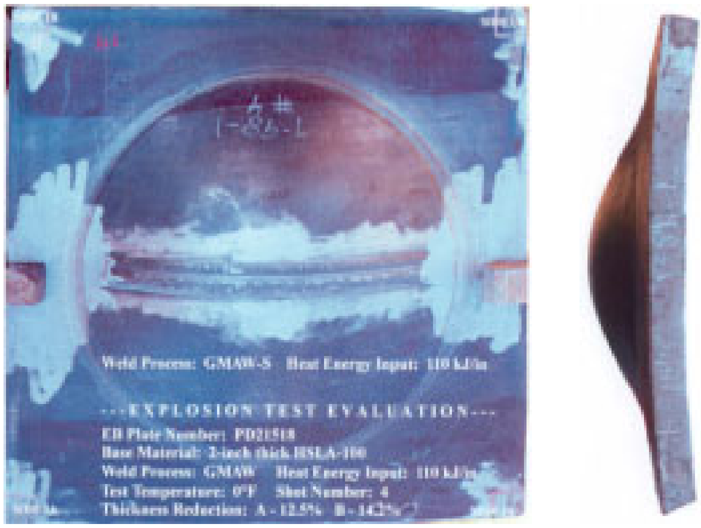
Technology Readiness Level 6: Model/Prototype Tests

Representative model or prototype system, which is well beyond the bread-board tested at TRL 5 and is tested in a relevant environment.

The evaluation of HSLA-100 steel production plates concluded that the mechanical properties of production plate, welding and weldability screening tests, fatigue properties, and corrosion properties demonstrated that the system was viable for certification for combatant ship structure. Evaluation as a system by explosion bulge and crack-starter bulge tests, fragment penetration resistance tests, and ballistic property tests was demonstrated in the next phase.

Fragment Penetration Resistance HSLA-100 Test Weldment

Explosion bulge and crack starter explosion bulge tests of 2-inch thick weldments by Gas Metal Arc Welding (GMAW), SMAW, and SAW of HSLA-100 steel were successfully conducted. The weldments were fabricated within the recommended preheat/ interpass temperatures expected for HSLA-100 fabrication. They exhibited no indications of hydrogen damage and passed the explosion bulge test requirements.



Explosion Bulge Test of HSLA-100 2-inch Thick Weldment

In 1987, NAVSEA initiated projects at Electric Boat Corporation and Newport News Shipbuilding (NNS) to evaluate the weldability of HSLA-100 steel under various preheat conditions in a production environment. The results of the weldability evaluation demonstrated that HSLA-100 steel could be welded at up to 1.25-inch thick at 60 ºF minimum preheat, with the same processes and consumables being used for HY-80/100 steels.

Based on NNS' welding and weldability evaluations of HSLA-100 using HY-100 welding consumables, welding preheat/interpass temperature limits were established. Preheat was recommended for SAW and SMAW, based on the weld metal cracking tendencies noted for these flux-assisted processes in the weldability testing. For GMAW and SAW, difficulties were experienced in obtaining MIL-100S-2 and MIL-120S-2 wire electrodes (low hydrogen content) with acceptable wire-feed characteristics for elimination of preheat for heavy-gage plate welding. Research projects are in progress to develop welding consumables specifically for HSLA-100 to achieve preheat-free welding in heavy plate, highly restrained welds.

Ballistic evaluations demonstrated that HSLA-100 steel and GMAW (MIL-100S-1) weldments (fabricated without preheat) were equivalent to HY-100 steel and weldments in ballistic resistance. Both steels were comparable to Army Rolled Homogeneous Armor.

NNS completed weld qualification and weldability testing to conduct pulsed-arc GMAW and SAW of HSLA-100 in thicknesses greater than 1 inch through 1-5/8 inch at 60 ºF preheat using MIL-100S-2 electrode. NAVSEA approved the procedures. It should also be noted that Ingalls Shipbuilding Division (ISD) conducted weld qualification and weldability tests of HSLA-100 up to 1-inch gage using both HY-100- and HY-80-type welding consumables and processes.

The present material specification for HSLA-80 and HSLA-100 steel strip, sheet, and plate is MIL-S-24645A, with Amendment 1 of 24 September 1990. HSLA-100 was certified by NAVSEA for surface ship construction in thicknesses up to 4 inches, 13 March 1989.

Key References:

Crement, D., *Weldability Study of HSLA-100 Steel, Phase I (HY-100 Welding Consumables),* Ingalls Shipbuilding Division, Welding Engineering Report, August 27, 1987.

Crement, D., *Weldability Study of HSLA-100 Steel, Phase I (HY-80/HSLA-80 Welding Consumables),* Ingalls Shipbuilding Division, Welding Engineering Report, January 29, 1988.

Fairbanks, M., *HSLA-100 Weldability Testing,* Electric Boat Division of General Dynamics Corporation, Report Task 11.1, Contract No. 00024-85-C-2055, September 1987.

Salive, M.L., R.A. Martin, and E.J. Mossi, *Results of Ballistic Tests of 2.25- and 3.75-Inch HSLA Steel (U),* DTRC(C) 89/002, April 1989 (CONFIDENTIAL).

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Schwietzer, N.F., *Explosion Test Evaluation of 2-Inch Thick HSLA-100 Weldments Fabricated by Newport News Shipyard Using the Submerged Arc "Twin Wire" and the Gas Metal Arc-Pulsed Welding Processes With Type MIL-100S-1 Filler Metal,* Mare Island Naval Shipyard, Engineering Technical Report, Project 138-74-88A, January 1989.

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Thomas, P.D., *Evaluation of the Weldability of HSLA-100 as a Substrate for Corrosion-Resistant Cladding and for Joining to Dissimilar Steels,* Newport News Shipbuilding and Drydock Company, Report No. E80(S11D)-2, Contract No. 00024-87-C-2012, Task No. 95, 6 September 1989.

Thomas, P.D., *HSLA-100 Weld Process Development,* Newport News Shipbuilding and Drydock Company, Welding Engineering Technical Report No. ES11D-1, Contract No. 00024-87-C-2012, Task No. 94, 1 May 1990.

Thompson, R.D., *First Article Qualification Testing of USX Corporation, USS Gary Works Division HSLA-100 Steel to the Requirements of MIL-S-24645A(SH) (DRAFT),* Mare Island Naval Shipyard, Engineering Technical Report, Project 138-23-89, January 1990.

Wallace, D.T., *HSLA-100 Weldability Evaluation,* Newport News Shipbuilding and Drydock Company, Report No. E.80-7, Contract No. N00024- 85-C-2056, June 1988.

Wallace, D.T., *HSLA-100 Weldability Tests for CVN-73 Material Substitution for HY-100 Steel,* Newport News Shipbuilding and Drydock Company, Report No. E.80 (S11D)-1, Contract No. N00024-88-C- 2044, February 1989.

Technology Readiness Level 7:
Prototype Near or at Planned Operational System

TRL-7 is a major step from TRL 6, requiring the demonstration of an actual prototype in an operational environment.

The fabrication of a series of structural performance models was completed under shipyard welding conditions. Holding bulkhead panel models, foundation models, and a full-scale foundation were evaluated and demonstrated satisfactory structural performance.

The Electric Boat Division [General Dynamics Corporation] fabricated the full-scale foundation and a small, heavy-gage tank model. NNS partially completed the fabrication of a full-scale hard tank; however, a funding shortage precluded tests. In these shipyard fabrication exercises, all weld cracking was related to SMAW and SAW consumables (where cracking occurred even when HY-100 preheat temperatures were used) or to improper welding practices. No HAZ cracking occurred in HSLA-100.

HSLA-100 Steel/LC-100 Weld Metal Box-Tank Fatigue Model (Overall View of Model Exterior/End Hatch Open)

Hydrostatic tests of full-gage bulkhead panel models are an extreme test of plating-to-stiffener strength and HAZ ductility. The HSLA-100 panel models exceeded anticipated holding pressure levels, withstanding over twice the holding pressure of identical HY-100 panel models. A series of foundation beam elements (full-scale) and the full-scale SSN 688-type AC foundation were installed and tested on a floating shock platform. The structures were subjected to a series of underwater explosion (UNDEX) shock tests. For a series of 3 UNDEX events, the structural response of the HSLA-100 items indicated no cracking or excessive deformation in any structural joint.

HSLA-100 Holding Bulkhead Panel Model:
Before Test (Left) and After Hydrostatic Test to Rupture (Right)

Key References:

Czyryca, E.J., *Assessment of HSLA-80 and HSLA-100 Steels for Submarine Non-Pressure Hull Applications,* CARDIVNSWC-TR-61-94/38, Preliminary, February 1995.

Fugate, S.P., *Fabrication of the HSLA-100 Foundation Structure,* Electric Boat Division of General Dynamics Corporation, Report No. 276, Contract No. 00024-86-C-2059, June 1988.

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Spaulding, R.S., P.D. Thomas, and R.A. Spitzer, *HSLA-100 Hard Tank Fabrication and Fatigue Model, Design and Fabrication Report,* Newport News Shipbuilding and Drydock Company, Report G2001- 0059, Contract No. N00024-87-C-2012, 9 September 1988.

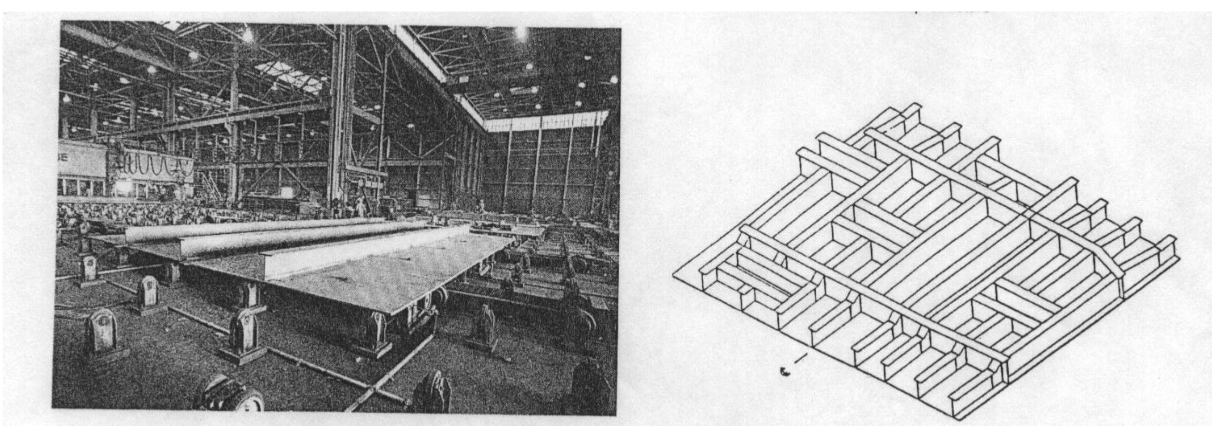
Thomas, P.D., *HSLA-100 Hard Tank Fabrication and Fatigue Model Construction,* Newport News Shipbuilding and Drydock Company, Report No. ES10-1, Contract No. 00024-85-C-2056, 29 July 1988.

Technology Readiness Level 8: Technology Demonstrated In Operation

Technology has been proven to work in its final form and under expected conditions.

In 1989, NAVSEA certified HSLA-100 steel for surface ship construction in thicknesses up to 4 inches. At that time, the *USS John C. Stennis* (CVN 74) was approved, indicating that HSLA-100 steel was a qualified substitute for HY-80/100 steel in CVN construction. Fabrication was to be conducted in accordance with MIL-STD-1689A(SH), *Fabrication, Welding, and Inspection of Ships Structure*. The experience base for welding HSLA-100 steel was too limited to allow the wholesale substitution for all HY-80/100 steel in the unrestricted areas of the carrier. Therefore, an implementation plan for incorporating HSLA-100 steel was submitted, and NAVSEA approved this plan.

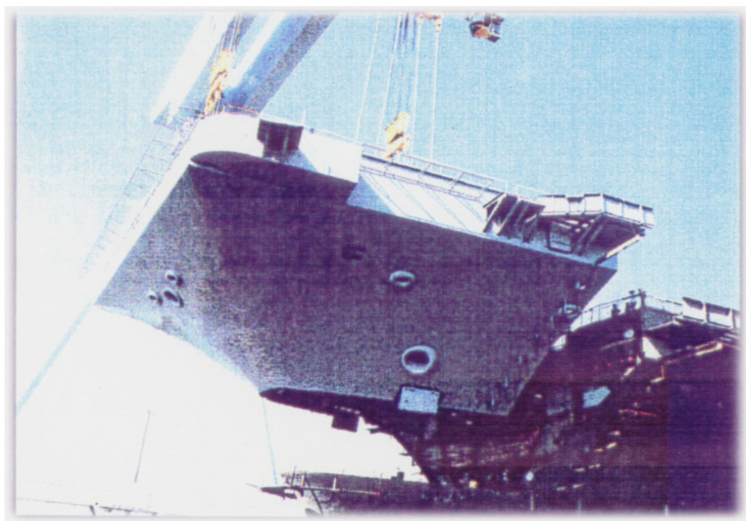
The CVN 74 main deck was the chosen area for HSLA-100, and approximately 770 LT were earmarked. The thicknesses in this area were 7/8-inch and 1-inch thick HSLA-100. The fabrication results were excellent. A total of 16,656 inches of butt joints in the 7/8-inch thick plate were welded, with only 8 inches requiring repair. In the 1-inch plate, 16,524 inches of butt joints were welded, and no defects were found. Since the ship was under construction at the time of the implementation plan, the total tonnage inserted into CVN 74 was limited to 1,250 LT, mostly above main deck.



CVN 74 HSLA-100 Steel Main Deck Panel Fabrication

NNS used HSLA-100 steel during CVN 74 construction. Approximately 700 tons of HSLA-100 steel plate in 7/8- and 1-inch thicknesses were used for main deck panel assemblies with longitudinal and transverse stiffeners without preheat (65 to 80 ºF shop temperature). One hundred percent magnetic particle inspection (MT) was performed on all HSLA-100 butt welds. In 1,400 feet of 7/8-inch thick HSLA-100 butt weld inspected by MT, only 2 repairs (8 inches total) were required, not related to hydrogen-type defects. The same length of 1-inch thick HSLA-100 butt weld inspected by MT showed no defects. A total of 1,250 tons of HSLA-100 were used in CVN 74, with over 4,000 feet of weldment inspection requiring 32 inches total repair (less than 0.01 percent).

NNS completed weld qualification and weldability testing to conduct pulsed-arc GMAW and SAW of HSLA-100 in thicknesses greater than 1 inch through 1-5/8 inch at 60 °F preheat using MIL-100S-2 electrode. NAVSEA approved the procedures. ISD conducted weld qualification and weldability tests of HSLA-100 up to 1-inch gage using both HY-100- and HY-80-type welding consumables and processes. The flight deck of the *USS Bataan* (LHD 5) and subsequent vessels of the same class were successfully fabricated with HSLA-100 plate (in place of HY-100 steel) for cost savings.



Key References:

Christein, J.P. and J.L. Warren, "Implementation of HSLA-100 Steel in Aircraft Carrier Construction – CVN 74," *Journal of Ship Production*, Society of Naval Architects and Marine Engineers, 1994.

Technology Readiness Level 9: Implementation of the Technology in Service

Actual application of the technology in its final form and under mission conditions.

Because of the experience gained on CVN 74, wholesale changes to HSLA-100 were made on CVN 75. Approximately, 10,500 LT of HSLA-100 were inserted into CVN 75. Most of the replacement was for decks and bulkheads and some built-up stiffeners. The HSLA-100 stiffeners were short spans with heavy web/flange members. HSLA-100 steel was selected to replace HY-100 for fabrication cost reduction, and, as a result, HSLA-100 steel has been used in place of HY-100 in the construction of *USS John C. Stennis* (CVN 74), *USS Harry S. Truman* (CVN 75), and *USS Ronald Reagan* (CVN 76).

On CVN 76, NAVSEA 08 approved the substitution of HSLA-100 for HY-80/100 structures outside the primary shield tank, opening another area for substitution. On CVN 77, expended use of HSLA-100 plate continues. NNS expects to qualify reduced preheat for welding up to 2 inches, adding over 4,000 LT of HSLA-100 where significant fabrication cost reduction is gained over HY-100 in this thickness range. Depending on complexity of the structure, estimated cost savings, for HSLA-100 vs. HY-100 fabrication in CVN 74 construction range from $500 to $3,000 per ton of fabricated structure.

The table below summarizes the tonnage of HSLA-100 steel plate used to date in construction of U.S. Navy combatant ships. The continued expansion of the use of HSLA-100 steel is planned for CVNX (CVN 78) design, including the heavy plating and foundation in the propulsion area.

Class	Vessels	LT
CVN 68	CVN 74	2,080
	CVN 75	11,600
	CVN 76	12,500
	CVN 77	12,500
LHD 1	LHD 5	1,180
	LHD 6	1,200

ACRONYMS FOR APPENDIX D

ASM	American Society for Metals International
ASTM	American Society for Testing and Materials
ATD	Advanced Technology Demonstration
CG	Carrier Group
CVN	Aircraft Carrier, Nuclear
CVNX	Aircraft Carrier, Nuclear, Experimental
DDG	Guided Missile Destroyer
DT&E	Developmental Test and Evaluation
DTNSRDC	David Taylor Naval Ships Research and Development Center
DTRC	David Taylor Research Center
FFG	Guided Missile Frigate
GMAW-P	Pulsed Gas Metal Arc Welding
GMAW-S	Short Circuiting Gas Metal Arc Welding
GMLRS	Guided Multiple Launch Rocket System
HAZ	heat-affected zone
HSLA	High-Strength Low-Alloy
HY	High Yield Strength (steel)
IMU	Inertial measurement Unit
INCO	International Nickel Company
ISD	Ingalls Shipbuilding Division
LHD	Amphibious Assault Ship
LRIP	low rate initial production
LSD	Dock Landing Ship
LT	long ton
NAVSEA	Naval Sea Systems Command
NNS	Newport News Shipbuilding
OT&E	Operational Test and Evaluation
OTC	Offshore Technology Conference
RLG	Ring Laser Gyro
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
SME	Society for Mining, Metallurgy, and Exploration

TM	Technical Manual
TRL	Technology Readiness Level
UNDEX	underwater explosion
AIME	American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.
MIL-S	Military Specification
MIL-STD	Military Standard
SDD	System Development and Demonstration
SSN	Attack submarine (Nuclear Propulsion)
MT	magnetic particle inspection